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Bethesda, Maryland 20084

LEVEL

PERFORMANCE PREDICTIONS FOR PLANING CRAFT IN A SEAWAY

BY

E. NADINE HUBBLE

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SHIP PERFORMANCE DEPARTMENT REPORT

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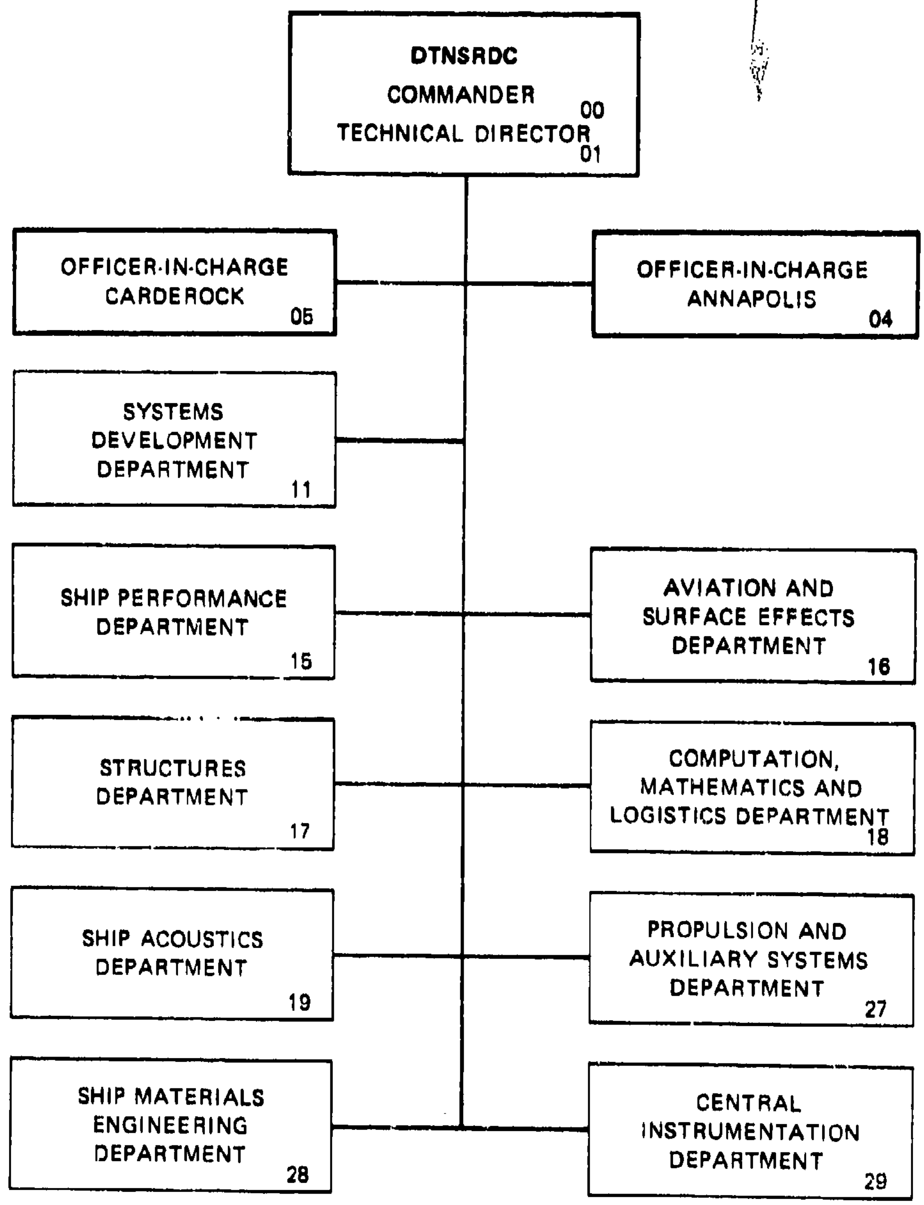
PERFORMANCE PREDICTIONS FOR PLANING CRAFT IN A SEAWAY

MAJOR DTNSRDC ORGANIZATIONAL COMPONENTS



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A procedure for the prediction of powering requirements and vertical accerations at the preliminary design stage is presented for planing hulls with propellers on inclined shafts. Envelopes of operating speed versus wave height are developed based on (1) maximum speed in seaway due to limits of the prime movers and/or propellers and (2) human endurance limits due to vertical accelerations. Complete documentation of the computer program is provided in the appendix. Sample computations and plots are presented for a typical planing craft.

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NOTATION

a_{BOW}	Average 1/10 highest vertical acceleration at 90% L_{OA} forward of transom
a_{CG}	Average 1/10 highest vertical acceleration at center of gravity
B_{PX}	Maximum breadth over chines
D	Propeller diameter
EAR	Propeller expanded area ratio
$F_{n\nabla}$	Speed-displacement coefficient
g	Acceleration of gravity
$H_{1/3}$	Significant wave height
J	Propeller advance coefficient
K_T	Propeller thrust coefficient
K_Q	Propeller torque coefficient
L_{OA}	Overall length of hull
L_P	Projected chine length of hull
$L_P/\nabla^{1/3}$	Slenderness ratio
m_g	Gear ratio
n	Rate of revolution per second; rps
N	Rate of revolution per minute; rpm
P_B	Brake power
P_D	Power delivered at propeller
P_S	Shaft power
Q	Torque

NOTATION
(continued)

Q_c	Propeller torque load coefficient
R_a	Resistance of appendaged hull in calm water
R_{aw}	Added resistance in rough water
R_b	Resistance of bare hull in calm water
R_t	Total resistance
T	Thrust
V	Ship speed
V_A	Speed of advance of propeller
Z	Number of propeller blades
1-t	Thrust deduction factor
1-w	Thrust wake factor
∇	Displaced volume
Δ	Displacement
η_a	Appendage drag factor
η_D	Propulsive efficiency
η_O	Propeller open-water efficiency
η_R	Relative rotative efficiency
ρ	Water density
σ	Cavitation number based on advance velocity
$\sigma_{0.7R}$	Cavitation number based on resultant water velocity at 0.7 radius of propeller
τ	Trim angle
τ_c	Propeller thrust load coefficient

ABSTRACT

A procedure for the prediction of powering requirements and vertical accelerations at the preliminary design stage is presented for planing hulls with propellers on inclined shafts. Envelopes of operating speed versus wave height are developed based on (1) maximum speed in seaway due to limits of the prime movers and/or propellers and (2) human endurance limits due to vertical accelerations. Complete documentation of the computer program is provided in the appendix. Sample computations and plots are presented for a typical planing craft.

ADMINISTRATIVE INFORMATION

This project was authorized and partially funded by the Naval Sea Systems Command Detachment Norfolk (NAVSEADET Norfolk) Work Request N64281 80 WR 0 0062 under Work Unit 1-1524-712. Development of the program was also partially funded by the David W. Taylor Naval Ship R&D Center (DTNSRDC) Ship Performance and Hydromechanics Program under Work Unit 1-1500-104.

INTRODUCTION

NAVSEADET Norfolk requested DTNSRDC to develop a computer routine to predict the operational limits of planing craft in a seaway based on state-of-the-art technology.

The computer program predicts the resistance, thrust requirements, and vertical acceleration of a planing hull for a matrix of speeds and significant wave heights. It also estimates the maximum thrust, as a function of speed, which can be developed with pre-selected prime movers, reduction gears, and propellers on inclined shafts. Speed, wave-height envelopes are then established based on the power limits of the propulsion system and the endurance limits of the crew due to accelerations. This program labeled PHPRLM is completely documented in Appendix A, with sample input and output in Appendix B. A similar program for a waterjet propulsion system is documented in Reference 1. Both programs augment the planing hull feasibility model program PHFMOPT[2] and should eventually be incorporated into the master program.

[1]References are listed on page 10.

PROCEDURE

THRUST REQUIREMENTS

The calm-water, bare-hull resistance R_b is generally derived from the synthesized Series 62-65 resistance curves presented in Figure 9 of Reference 2. However, if more precise data are available, e.g., model experiments of the exact hull or a similar form, this resistance data can be input directly for the matrix of speeds considered. Resistance of the appendaged hull R_a is approximated using appendage drag factors η_a either from Reference 3 or direct input if other data is available; $R_a = R_b/\eta_a$. Added resistance in rough water R_{aw} is predicted from an empirical equation recently developed by a regression analysis of planing hull rough-water experimental data.[4]

$$R_{aw}/\Delta = 1.3 \quad (H_{1/3}/B_{PX})^{0.5} \quad F_{n\nabla} \quad (L_P/\nabla^{1/3})^{-2.5}$$

where $F_{n\nabla} = V/(g\ \nabla^{1/3})^{\frac{1}{2}}$

The total resistance for the hull then is $R_t = R_a + R_{aw}$. Thrust deduction factors 1-t from either Reference 3 or direct input are used to calculate the thrust requirement $T = R_t/(1-t)$.

PROPELLER CHARACTERISTICS

Propeller open-water characteristics are derived as a function of pitch ratio P/D, expanded area ratio EAR, and number of blades Z with coefficients developed from the Wageningen B-Screw Series.[5] Thrust and torque coefficients K_T and K_Q for flat face, segmental section propellers such as the Gawn-Burrill Series[6] tend to be slightly higher than the B-Screw airfoil section propellers. This difference can essentially be taken into account by varying the EAR and/or P/D used in the open-water equations. If actual open-water data are available for the selected propeller, these data can be input to the program.

The propeller characteristics in a cavitating environment are derived from the maximum thrust and torque load coefficients τ_c and Q_c developed as a function of cavitation number at 0.7 radius $\sigma_{0.7R}$ for several propeller series in Reference 7. Options are available in the program for tabulating and/or plotting (see Figure 1) the propeller K_T

and K_Q as a function of advance coefficient J for the open-water condition as well as the transition and fully cavitating regions at several cavitation numbers σ . These "transition" curves do not exactly match the shape of experimental cavitation data since they represent only 80 percent of the maximum thrust and torque lines developed in Reference 7 and are not faired into the point of K_T or K_Q breakdown. The 80 percent criteria is based on full-scale trial data which indicates actual thrust and torque in the transition region to be less than the maximums derived from the propeller series data -- see Figures 5 and 6 of Reference 7. For Gawn-Burrill type propellers, the 10 percent back cavitation line shown in Figure 23 of Reference 6 is used as a design criteria for adequate blade area. The tabulated output is marked with the letter C to represent thrust which exceed the 10 percent cavitation criteria or with a * when 80 percent of maximum thrust is attained. The thrust at which 10 percent back cavitation occurs is represented by a dash line on the thrust-speed curves shown in Figure 2.

POWER REQUIREMENTS

After the thrust requirements are computed for the matrix of speeds and wave heights desired, J, K_T, and then K_Q are interpolated from the propeller characteristic curves as functions of thrust loading K_T/J^2 and σ . Corresponding propeller rpm N, torque Q, delivered horsepower P_D, propulsive efficiency η_D, propeller efficiency η_0, etc. are then calculated. Thrust wake factor 1-w from either Reference 3 or input are used, with the relative rotative efficiency η_R assumed to be one, i.e., torque wake equal to thrust wake (torque required in open water is equal to that required behind the ship).

ENGINE TORQUE-RPM LIMITS

Engine characteristics are input as an array of engine rpm versus brake power P_B values covering the operational range of the engines. Gear loss and shaft loss constants, generally about 2 percent each, are used to estimate the corresponding shaft power P_S and the power delivered at the propeller P_D. For a given gear ratio m_g the corresponding propeller

rpm and torque limits are then established. If the gear ratio is not input, the program will compute an optimum for maximum speed in a specified sea state.

$$m_{g_{opt}} = \frac{\text{engine rpm at maximum power of engines}}{\text{propeller rpm required in specified sea, at max. engine power}}$$

The available thrust at the torque limits of the prime movers is derived after interpolation of the propeller data to obtain J, K_Q, then K_T as functions of torque loading K_Q/J^2 and σ. Similarly the thrust at maximum rpm is obtained after interpolation for K_T as functions of J and σ. A sample illustration of thrust requirements and thrust limits due to maximum rpm and torque of the prime movers is shown in Figure 2 for a typical planing hull with diesel engines. Diesel engines generally operate with nearly constant torque whereas gas turbines have nearly constant rpm. The upper bound of the rpm limit curve corresponds to the "transition" region of the propeller characteristic curves and represents the maximum thrust which can be developed by the propellers unless operating in the supercavitating regime, at low J's.

MAXIMUM SPEED

The maximum speed attainable in a given sea state is represented by the intersection of the thrust requirement curve and the thrust limit curve due to either engine torque or rpm restriction, whichever occurs first. With an optimum gear ratio, maximum speed for a specified sea state is attained at maximum power of the prime movers, i.e., intersection of torque limit and rpm limit curves. The maximum speed is derived for each wave height. Figure 3 shows a sample graph of wave height vs maximum speed. The computations and plots can be made for 1 to 4 different gear ratios for each case, one of which can be the optimum m_g derived in the program.

HABITABILITY LIMITS

Average 1/10 highest vertical accelerations at the center of gravity a_{CG} and at the bow a_{BOW} (90% of the overall length forward of the transom) are estimated for the matrix of speeds and wave heights with empirical equations recently derived from experimental data.[8]

$$a_{CG} = 7.0 \ (H_{1/3}/B_{PX}) \ (1 + \tau/2)^{0.25} \ (L_P/B_{PX})^{-1.25} \ F_{n\nabla}$$

$$a_{BOW} = 10.5 \ (H_{1/3}/B_{PX}) \ (1 + \tau/2)^{0.50} \ (L_P/B_{PX})^{-0.75} \ F_{n\nabla}^{\ 0.75}$$

The accelerations at any location between the CG and the bow, such as the helmsman's station, can then be approximated by linear interpolation. These data are interpolated to obtain speed, wave-height envelopes for average 1/10 highest vertical accelerations of 1.0 g, representing the endurance limit of the crew for 4 to 8 hours, and 1.5 g, representing the endurance limit for 1 to 2 hours. Sample speed, wave-height envelopes are shown in Figure 3.

PROPELLER SELECTION

The program can be run with any number of propeller sets to aide in the selection of optimum parameters. P/D, EAR, and Z must be input for each set. Propeller diameter D may either be input or selected by the following method. Design speed and wave height are input and the corresponding thrust requirement is computed. A design power, not exceeding the maximum power of the prime movers, is also input. A minimum diameter D_{min} is computed from the thrust loading K_T/J^2 corresponding to the 10 percent back cavitation criteria from Reference 6. A maximum diameter D_{max} is computed from K_T/J^2 at peak open-water efficiency. The power and rpm requirements at design speed are also computed for several D's in 5-inch increments from D_{min} to D_{max}. D_{min} is selected as the optimum diameter if the power required with D_{min} does not exceed the design power. Optimum diameter is interpolated from the 5-inch increment array of D's if design power falls between the power requirements for D_{min} and D_{max}. When design power exceeds the requirements for both D_{min} and D_{max}, D_{max} is selected as the diameter except for the following case. When D_{min} is actually greater than D_{max}, indicating more than 10 percent cavitation at peak efficiency, D_{min} is the diameter selected. The optimum diameter is always rounded up to the next full inch.

No selection process for P/D or EAR is built into this program since many different factors may influence a particular design. However, numerous sets of parameters can be run for each case at minimal cost for use in the development of design charts. In the diameter selection routine, diameters corresponding to even increments of 100 rpm are interpolated from the array of 5-inch increment diameters. These values can be used for plotting contours of rpm on the propeller design charts to aide in the selection of a propeller to match specific engine and/or gear ratio requirements.

COMMENTS

This program, together with the planing hull feasibility model program PHFMOPT, is quite useful for making timely preliminary design studies for planing craft. It can also be used for displacement ships since the program has options for input of the resistance and propulsion coefficients, but this program does not take into account any difference in thrust and torque wake.

Some means of predicting roll at the preliminary design stage is also desirable for enhancement of this program. A low-speed roll criteria needs to be established for completely defining the speed, wave-height envelope.

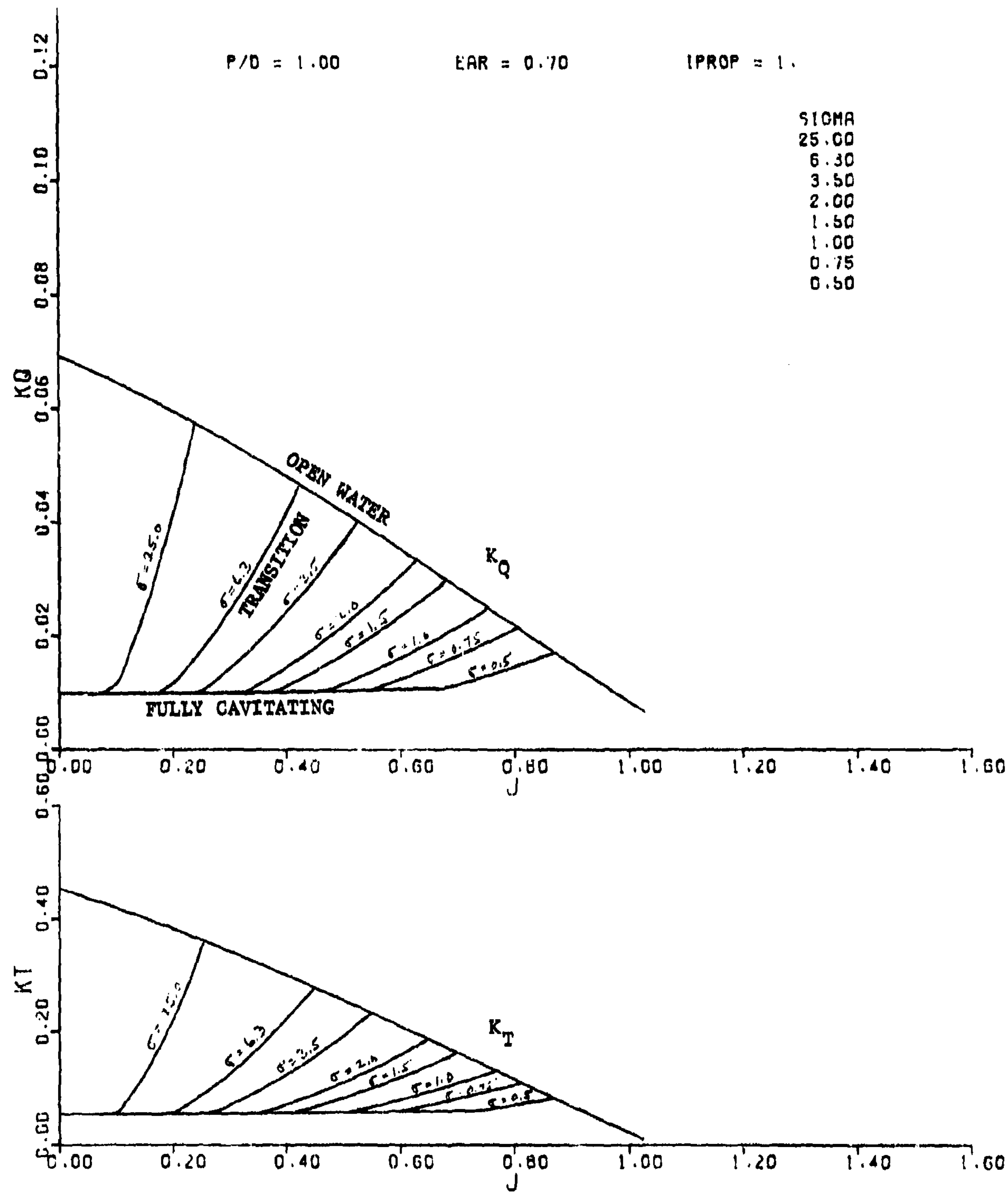

Figure 1 - Propeller Characteristics in Open Water and Cavitating Environment

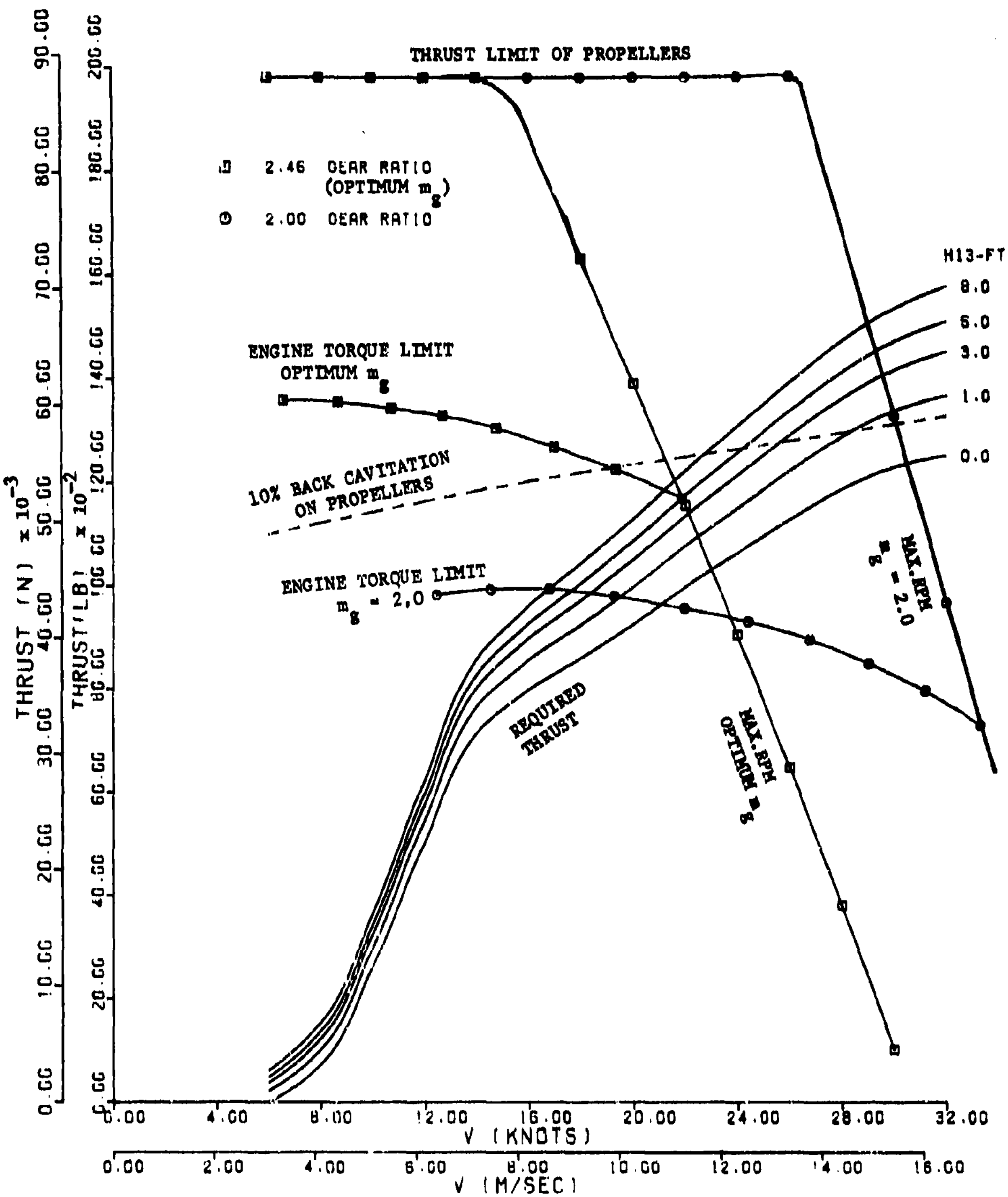

Figure 2 - Thrust Curves for Planing Craft with Twin Propellers and Diesel Engines

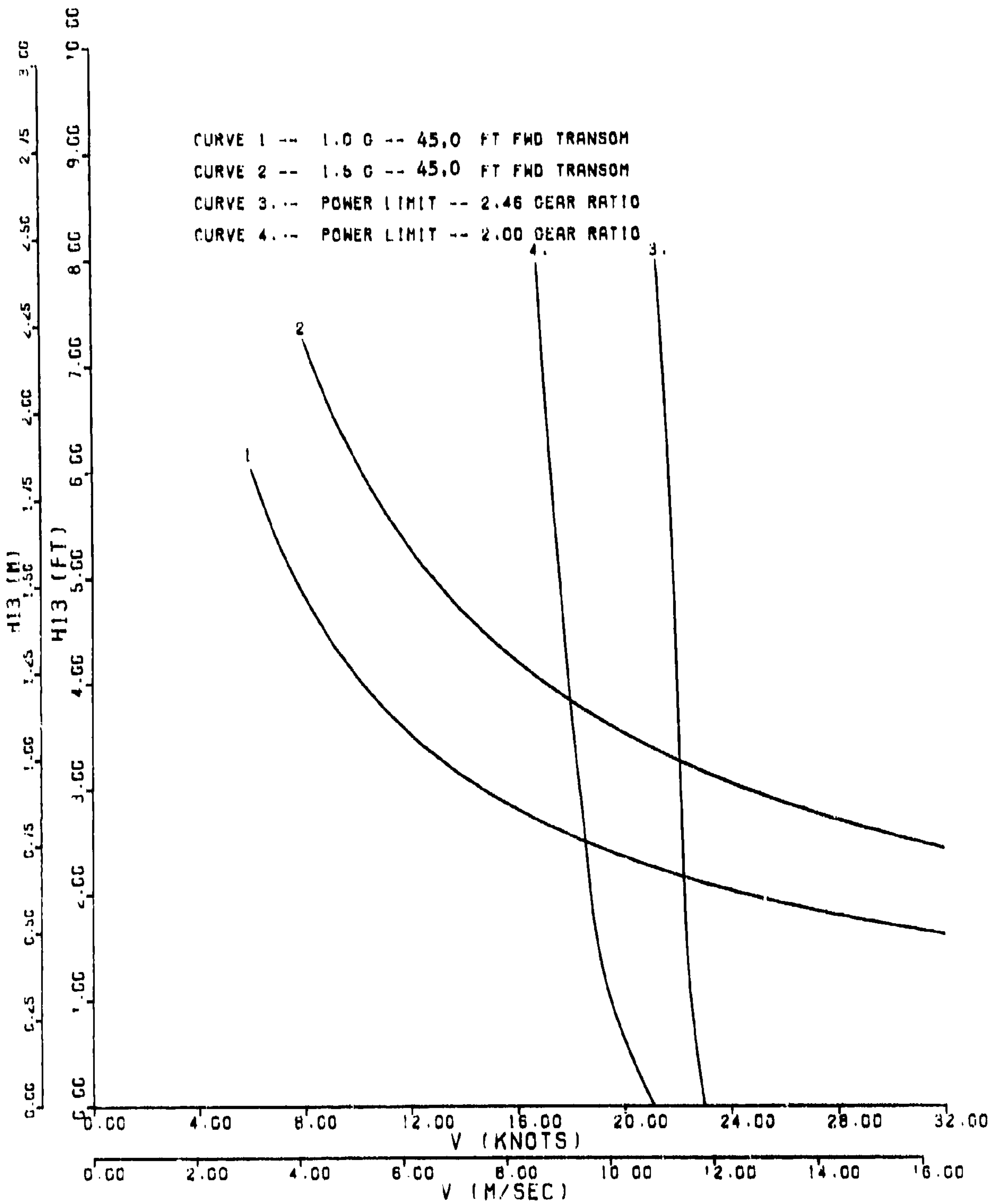

Figure 3 - Operating Limits for Planing Craft in Seaway

REFERENCES

1. Hubble, E. N., "Performance Predictions for Four Proposed Designs of a 28-ft Survey Launch," DTNSRDC Report SPD-0902-01 (Jul 1979).

2. Hubble, E. N., "Program PHFMOPT, Planing Hull Feasibility Model, User's Manual," DTNSRDC Report SPD-0840-01 (Revised Aug 1979).

3. Blount, D. L. and D. L. Fox, "Small Craft Power Predictions," Marine Technology, Vol. 13, No. 1 (Jan 1976).

4. Hoggard, M. M., "Examining Added Drag of Planing Craft Operating in a Seaway," Paper presented to Hampton Road Section, SNAME (Nov 1979).

5. Oosterveld, M.W.C. and P. Van Oossanen, "Further Computer Analyzed Data of the Wageningen B-Screw Series," International Shipbuilding Progress Vol. 22 (Jul 1975).

6. Gawn, R.W.L. and L. C. Burrill, "Effect of Cavitation on the Performance of a Series of 16 Inch Model Propellers, Trans. INA, Vol. 99 (1957).

7. Blount, D. L. and D. L. Fox, " Design Considerations for Propellers in a Cavitating Environment," Marine Technology (Apr 1978).

8. Hoggard, M. M. and M. P. Jones, "Examining Pitch, Heave, and Accelerations of Planing Craft Operating in a Seaway," Paper presented at High-Speed Surface Craft Exhibition and Conference, Brighton (Jun 1980).

APPENDIX A

DOCUMENTATION OF SUBPROGRAMS FOR PHPRLM

NAME:	PROGRAM PHPRLM		
PURPOSE:	(1) Predict the resistance, thrust requirements, and vertical accelerations of a planing hull for a matrix of speeds and significant wave heights. (2) Determine maximum speed obtainable at each wave height with pre-selected prime mover(s) and propeller(s). (3) Determine wave heights versus speed corresponding to human acceleration endurance limits of 1.0 g and 1.5 g		
SUBPROGRAMS:	PRCOEF, PHRES, SAVIT, PRCHAR, PRINTP, HPLOT, TPLOT, MINP, YINTE, YINTX, CALCOMP Routines **PLOT & PLOTS**		
INPUT:	Via Punched Cards	Card	Columns
NCASES	Number of cases--repeat following set of cards for each case	1	1-4
TITLE	Identification for hull design	2	1-80
XLOA	Overall length of hull (L_{OA}) in ft	3	1-8
PL	Projected chine length of hull (L_p) in ft	3	9-16
BPX	Maximum beam over chines (B_{PX}) in ft	3	17-24
HT	Draft at transom (T_A) in ft	3	25-32
DLBS	Displacement at rest (Δ) in lb	3	33-40
BETAM	Deadrise angle at midships (β_m) in deg	3	41-48
XLCG	Distance of center of gravity forward of transom ($\overline{AG}$) in ft	3	49-56
VCG	Distance of center of gravity above baseline ($\overline{KG}$) in ft	3	57-64
XACC	Distance forward of transom in ft at which accelerations are to be computed, in addition to CG and bow locations	3	65-72
FTRIM	Fixed trim angle (τ) in deg If not input, program will use Savitsky prediction of trim at each speed	3	73-80
PEMAX	Maximum brake horsepower of each prime mover ($P_{e_{max}}$)	4	1-8

		PROGRAM Card	PHPRLM Columns
REMAX	Maximum revolutions per minute (rpm) of prime mover Ne_{max}), corresponding to Pe_{max}	4	9-16
GL	Gear loss ratio (K_1) = brake horsepower/shaft horsepower	4	17-24
SL	Shaft loss ratio (K_2) = shaft horsepower/hp^2 developed at prop	4	25-32
RHO	Water density (ρ) in lb x sec^2/ft^4	5	1-8
VIS5	Kinematic viscosity of water (ν) in ft^2/sec x 10^5	5	9-16
GA	Acceleration of gravity (g) in ft/sec^2	5	17-24
DCF	Correlation allowance resistance predictions, generally zero	5	25-32
SDF	Standard deviation factor for resistance data. Use zero for mean Series 62-65 curves	5	33-40
NV	Number of speeds -- maximum of 20	6	1-4
NWH	Number of wave heights, including zero -- maximum of 5	6	5-8
NPR	Number of prime movers = number of propellers (n_{pr})	6	9-12
NE	Number of points input from engine characteristics curve -- maximum of 10	6	13-16
IPROP	Control for type of propellers 1 for Gawn-Burrill type (flat face, segmental sections) 2 for Newton-Rader type 3 for Wageningen B - Screw type (airfoil sections)	6	17-20
IPM	Control for type of prime movers 1 for diesel engines 2 for gas turbines	6	21-24

		Card	Columns
IPLOT	Control for graphical output, i.e., CALCOMP plots 0 for no plots 1 for plots of thrust vs speed and speed-wave height envelopes 2 for plots of propeller characteristics in addition to plots above	6	25-28
IPC	Control for propulsion coefficients 1 if thrust deduction factor (1-t), thrust wake factor (1-w), and appendage drag factor (η_a) are estimated by Subroutine PRCOEF 2 if 1-t, 1-w, and η_a are input	6	29-32
IRES	Control for bare hull resistance data 1 if resistance is estimated by Subroutine PHRES based on Series 62-65 data 2 if resistance is input	6	33-36
IOW	Control for propeller open-water characteristics 1 if computed by Subroutine OWKTQ based on Wageningen B-screw coefficients 2 if points from open-water curves are input	6	37-40
NJ	Number of points input from each open-water curve, if IOW = 2. Maximum of 60.	6	41-44
IPRT	Control for amount of printed output 0 for complete output (pages 1-10) 1 to omit engine characteristics and propeller characteristics (pages 2,4,5)	6	45-48
VKT	Array of ship speeds (V_K) in knots, in ascending order. Maximum of 20. Do not include zero speed. 10 speeds per card. Use 2 cards if NV>10	7	1-8 9-16 . . .

		Card	Columns
H13	Array of significant wave heights ($H_{1/3}$) in ft, in ascending order. Maximum of 5. First wave height must be zero.	8	1-8 9-16 ⋮
PE	Array of operating horsepower values for each prime mover (P_e), in ascending order. Maximum of 10.	9	1-8 9-16
RE	Array of rpm values for prime mover (N_e), corresponding to P_e values on card 9	10	1-8 9-16
TDF	Array of 1-t values corresponding to speeds on Card(s) 7. Use 2 cards if NV > 10. Omit Card(s) 11 if IPC = 1	11	1-8 9-16 ⋮
TWF	Array of 1-w values at each speed Omit Card(s) 12 if IPC = 1	12	1-8 9-16
ADF	Array of η_a values at each speed Omit Card(s) 13 if IPC = 1	13	1-8 9-16
RBH	Array of bare hull resistance (R_b) in lb at each speed. Appendaged resistance may be input if η_a is set to 1.0. Omit Card(s) 14 if IRES = 1	14	1-8 9-16 ⋮
JT	Array of propeller advance coefficients (J) in ascending order. Maximum of 60. 10 points per card. Omit Card(s) 15 if IOW = 1	15	1-8 9-16 ⋮
KTO	Array of propeller thrusts coefficients (K_T) in open-water corresponding to input J's. Omit Card(s) 16 if IOW = 1	16	1-8 9-16 ⋮
KQO	Array of propeller torque coefficient (K_Q) in open-water corresponding to input J's. Omit Card(s) 17 if IOW = 1	17	1-8 9-16 ⋮
NGR	Number of gear ratios considered --maximum of 4	18	1-4
NPROPS	Number of sets of propellers considered	18	5-8
GR	Array of gear ratios (m_g) If m_g = 0.0 is input, program will compute optimum value of m_g	19	1-8 9-16

		Card	Columns
DIN	Propeller diameter (D) in inches	20	1-8
PD	Propeller pitch/diameter ratio (P/D)	20	9-16
EAR	Propeller expanded area ratio (EAR)	20	17-24
Z	Number of blades per propeller	20	25-32
PEDES	Brake power of each prime mover used for sizing propeller	20	33-40
XI	Index of ship speed, from Card 7, for sizing propeller	20	41-48
XJ	Index of wave height, from Card 8, for sizing propeller and for calculating optimum m_g	20	49-56

If DIN > 0, do not input PEDES and XI

If DIN = 0, program will calculate a diameter based on above speed, wave height, and power

Values of P/D, EAR, and Z must be input.

Note: Repeat Card 20 for each set of propellers considered. Then repeat Cards 2 through 20 for each case.

OUTPUT:

Page 1 -- Echo of Input Data

Page 2 -- Characteristics of Prime Movers (Not Printed if IPRT > 0)

MAX.BHP	$P_{e_{max}}$	=	Maximum brake horsepower of each prime mover, input from Card 4
MAX.RPM	$N_{e_{max}}$	=	Maximum rpm of prime mover, from Card 4
GEAR RATIO	m_g	=	rpm of prime mover/propeller rpm from Card 4
BHP/SHP	K_1	=	gear loss ratio, input from Card 4
SHP/DHP	K_2	=	shaft loss ratio, input from Card 4
	n_{pr}	=	number of prime movers = number of propellers input from Card 4
BHP PER ENGINE	P_e'		points from engine characteristic curve, input from Cards 9 and 10
ENGINE RPM	N_e'		
TOTAL DHP	P_D'	=	total delivered horsepower at propellers
		=	$P_e\ n_{pr}\ /K_1\ /K_2$
PROP. RPM	N'	=	propeller rpm = $N_e/\ m_g$
Q-FT.LB	Q'	=	Maximum developed torque in ft-lb
		=	$33000\ P_D'/\ (2\ \pi\ N')$

Page 3 -- Propulsion Coefficients and Resistance

LOA-FT	L_{OA}	=	overall ship length in ft, input from Card 3
LP-FT	L_p	=	projected chine length in ft, from Card 3
BPX-FT	B_{PX}	=	maximum beam over chines in ft, from Card 3
HT-FT	T_A	=	draft at transom in ft, from Card 3
DISPL-LB	Δ	=	displacement at rest in lb, from Card 3
BETA-DEG	β_m	=	deadrise at midships in deg, from Card 3

LCG-FT	$\overline{AG}$	=	CG from transom in ft, from Card 3
VCG-FT	$\overline{KG}$	=	CG from baseline in ft, from Card 3
XACC-FT	X_{acc}	=	distance from transom in ft, at which accelerations are computed, from Card 3
C-LOAD	C_Δ	=	beam loading coefficient
		=	$\Delta / (\rho\ g\ B_{PX}^{\ 3}) = \nabla / B_{PX}^{\ 3}$
LP/V13	$L_p/\nabla^{1/3}$	=	slenderness ratio
LP/BPX	L/B	=	length-beam ratio, based on projected chine length and maximum chine beam
D-IN	D_{in}	=	propeller diameter in inches, from Card 4
P/D	P/D	=	propeller pitch ratio, from Card 4
EAR	EAR	=	propeller expanded area ratio, from Card 4
NPR	n_{pr}	=	number of propellers, from Card 4
V-KT	V_K	=	ship speed in knots, input from Card 7
V-LOA	$V_K/\sqrt{L}$	=	speed-length ratio based on overall length
FNV	$F_{n\nabla}$	=	speed-displacement coefficient
		=	$V / (g\nabla^{1/3})^{1/2}$
SIGMA	σ	=	cavitation number
1-T	1-t	=	thrust deduction factor
1-W	1-w	=	thrust wake factor = torque wake factor
EA	η_a	=	appendage drag factor

1-t, 1-w, η_a generated from Subroutine PRCOEF if IPC = 1
1-t, 1-w, η_a input from Cards 11, 12, 13 if IPC = 2

RB/W	R_b/W	=	resistance-weight ratio for bare hull in still water
	R_b		generated from Subroutine PHRES if IRES = 1
	R_b		input from Card 14 if IRES = 2
	W	=	weight of craft = displacement at rest Δ
RA/W	R_a/W	=	resistance-weight ratio for appendaged hull in still water
		=	$(R_b/W) / \eta_a$

EHPB	EHP_b	=	effective horsepower of bare hull
		=	R_b V / 550.
EHPA	EHP_a	=	effective horsepower of appendaged hull
		=	R_a V / 550

Page 4 -- Propeller Open-Water Characteristics (not printed if IPRT > 0)

IPROP		=	Indicator for propeller type, from Card 6
		=	1 for Gawn-Burrill type
		=	2 for Newton-Rader type
		=	3 for Wageningen B-screw type
D-IN	D_{in}	=	Propeller diameter in inches, from Card 20
D-FT	D	=	Propeller diameter in ft - $D_{in}/12$
P/D	P/D	=	Propeller pitch ratio, from Card 20
EAR	E.A.R	=	Propeller expanded area ratio, from Card 20
BLADES	Z	=	Number of blades per propeller, from Card 20
DEPTH-FT	h_o	=	depth of center of propeller below waterline in ft = T_A + 0.75 D
SIGMA/VSQ	σ/V_A^2	=	constant for cavitation number
		=	$(p_A + p_H - p_V)/(\rho/2)$
	p_A	=	atmospheric pressure = 2116 lb/ft^2
	p_V	=	vapor pressure = 36 lb/ft^2
	p_H	=	static pressure = $\rho g h_o$
AP-SQFT	A_P	=	Projected area of propeller in sq. ft
			$(\pi D^2/4)$ (EAR) (1.067 - 0.229 P/D)
	V_A	=	speed of advance = (1-w) V
	V	=	ship speed in ft/sec
J	J	=	propeller advance coefficient = $V_A/(nD)$
	n	=	propeller revolutions per second (rps)
KT	K_T	=	propeller thrust coefficient = $T/(\rho n^2 D^4)$
	T	=	thrust per propeller in l.

KQ	K_Q	=	propeller torque coefficient = $Q/(\rho\ n^2\ D^5)$
	Q	=	torque per propeller in ft-lb

Tables of open-water K_T and K_Q values generated from Subroutine OWKTQ if IOW = 1 or input from Cards 15-17 if IOW = 2.

EP	η_0	=	propeller open-water efficiency
		=	$(J/2\pi)\ (K_T/K_Q)$
KT/J2	K_T/J^2	=	propeller thrust loading = $T/(\rho\ D^2\ V_A^{\ 2})$
KQ/J^2	K_Q/J^2	=	propeller torque loading = $Q/(\rho\ D^3\ V_A^{\ 2})$
KQ/J3	K_Q/J^3	=	propeller power loading = $Qn/(\rho\ D^2\ V_A^{\ 3})$
TC	τ_c	=	thrust load coefficient = $T/(A_p\ V_{0.7R}^{\ 2}\ \rho/2)$
		=	$K_T/[\frac{1}{4}\ (A_p/D^2)\ (J^2 + 4.84)]$
QC	Q_c	=	torque load coefficient = $Q/(A_p\ V_{0.7R}^{\ 2}\ \rho/2)$
		=	$K_Q/[\frac{1}{4}\ (A_p/D^2)\ (J^2 + 4.84)]$
S.7/S	$\sigma_{0.7R}/\sigma$	=	$\dfrac{\text{cavitation number based on velocity at 0.7R}}{\text{cavitation number based on advance velocity}}$
		=	$J^2/(J^2 + 4.84)$
EPMAX	$\eta_{0_{max}}$	=	maximum propeller efficiency

Page 5 - Propeller Cavitation Characteristics (Not Printed if IPRT>0)

IPROP, D-IN, etc.		-	Same as Page 4
T1, T2, Q1, etc.		-	Constants from Subroutine CAVKTQ
SIGMA	σ	=	cavitation number
		=	$(p_A + p_H - p_V)\ /\ (1/2\ \rho\ V_A^{\ 2})$
J	J	=	advance coefficient = $V_A/(nD)$
KT	K_T	=	thrust coefficient = $T/(\rho\ n^2\ D^4)$
KQ	K_Q	=	torque coefficient = $Q/(\rho\ n^2\ D^5)$

Tables of K_T and K_Q at various σ's generated from Subroutine CAVKTQ

Page 6 - Propeller Sizing (Not Printed if Diameter is Input)

VA (FPS)	V_A	=	speed of advance in ft/sec
		=	V (1-w) where V is design ship speed
P/D	P/D	=	propeller pitch ratio
EAR	EAR	=	propeller expanded area ratio
NPR	n_{pr}	=	number of propellers = number of prime movers
BLADES	Z	=	number of blades per propeller
DIN	D_{in}	=	propeller diameter in inches
MIN. DIAM	D_{min}	=	minimum diameter based on 10% back cavitation criteria from Gawn-Burrill propeller series
MAX. DIAM	D_{max}	=	maximum diameter based on maximum propeller open-water efficiency
OPT. DIAM	D_{opt}	=	optimum diameter selected
DFT	D	=	propeller diameter in ft
SIGMA	σ	=	cavitation number based on V_A
KT/JSQ	K_T/J^2	=	thrust loading per propeller
JT	J_T	=	advance coefficient at K_T/J^2
KT	K_T	=	thrust coefficient at J_T
KQ	K_Q	=	torque coefficient at J_T
EP	η_0	=	propeller efficiency at J_T
	* after η_0		indicates operation at J above peak efficiency
PC	η_D	=	propulsive coefficient
T-LB	T	=	total thrust requirement in lb at design speed and wave height
	C after T		indicates more than 10% back cavitation
	* after T		indicates maximum thrust due to cavitation
Q-FT.LB	Q	=	total torque in ft-lb
RPM	N	=	propeller rpm
DHP	P_D	=	total power developed at propellers

Page 7 - Powering Requirements and Accelerations

LOA-FT, LP-FT, etc		-	Same as Page 3
V-KT	V_K	=	Ship speed in knots, input from Card 7
H13-FT	$H_{1/3}$	=	significant wave height in ft, from Card 8
RW/W	R_t/W	=	total resistance-weight ratio in seaway
		=	$(R_a/W) + (R_{aw}/W)$
	R_{aw}/W	=	added resistance-weight ratio in waves
		=	$1.3\ (H_{1/3}/B_{PX})^{0.5}\ (L_P/\nabla^{1/3})^{-2.5}\ F_{n\nabla}$ **(Reference 4)**
	T	=	total thrust requirements in lb
		=	$R_t/(1-t)$
KT/JSQ	K_T/J^2	=	thrust loading per propeller
		=	$T/(n_{pr}\,\rho\, V_A^{\ 2}\ D^2)$
JT	J_T	=	propeller advance coefficient corresponding to K_T/J^2
KT	K_T	=	propeller thrust coefficient at J_T
KQ	K_Q	=	propeller torque coefficient at J_T
EP	η_0	=	propeller efficiency at J_T
	* after η_0		indicates operation beyond peak efficiency, i.e., high J J_T, K_T, K_Q, η_0 generated from Subroutine PRINTP as function of K_T/J^2 and σ
	n	=	propeller rps = $V_A\ /\ (J_T\ D)$
T-LB	T	=	total thrust in lb = $K_T\,\rho\, n^2\ D^4\ n_{pr}$ check: $T = R_T\ /\ (1-t)$
	C after T		**indicates more than 10 percent back cavitation**
	* after T		indicates that thrust required exceeds maximum thrust limit of propeller due to cavitation -- unless the propeller can operate in the fully cavitating range, i.e., high rpm, low J_T.
Q-FT.LB	Q	=	total torque in ft-lb = $K_Q\,\rho\, n^2\ D^5\ n_{pr}$
	* after Q		indicates that torque required exceeds torque limit of the prime movers at the required rpm

RPM	N	= propeller rpm = 60 n
	* after N	indicates that rpm required exceeds rpm limit of the prime movers
DHP	P_D	= total horsepower developed at propellers = $2\pi\ Q\ n\ /\ 550$
	P_E	= total effective horsepower = $R_T\ V\ /\ 550$
PC	η_D	= propulsive coefficient = P_E/P_D check: $\eta_D = \eta_O\ \eta_H\ \eta_R$
	η_H	= hull efficiency = $(1-t)\ /\ (1-w)$
	η_R	= relative rotative efficiency = 1.0 since torque wake assumed equal to thrust wake
TRIM	τ	= trim angle in deg = fixed trim angle, if input from Card 3 otherwise trim generated by Subroutine SAVIT
CG ACC	a_{CG}	= average 1/10 highest vertical accelerations at the center of gravity in g's = $7.0\ (H_{1/3}/B_{px})\ (1 + \tau/2)^{0.25}\ (L_p/\nabla^{1/3})^{-1.25}\ F_{n\nabla}$
BOW ACC	a_{BOW}	= average 1/10 highest vertical acceleration at 90% of L_{OA} forward of transom in g's = $10.5\ (H_{1/3}/B_{px})\ (1 + \tau/2)^{0.5}\ (L_p/B_{PX})^{-0.75} F_{n\nabla}^{\ 0.75}$
X ACC	a_X	= average 1/10 highest vertical accelerations at location X_{acc} in g's = $a_{CG} + \ (a_{BOW} - a_{CG})\ (X_{acc} - LCG)/(0.9\ L_{OA} - LCG)$

Equations for a_{CG} and a_{BOW} from Reference 8.

Page 8 - 10 Percent Back Cavitation (Gawn-Burrill Propellers)

V-KT	V_K	=	ship speed in knots, from Card 7
SIGMA		=	cavitation number
T-LB	T	=	total thrust in lb at which 10% back cavitation occurs $\tau_c = 0.494\ \sigma_{0.7R}^{0.88}$
Q-FT.LB, RPM, DHP		=	corresponding values of torque, rpm, delivered power
J, KT, KQ, EP		=	corresponding propeller characteristics

Page 8 - Maximum Speed with Optimum Gear Ratio (Input $m_g = 0$)

V-KT	$V_{K_{max}}$	=	ship speed in knots attainable in specified sea with maximum power
H13-FT	$H_{1/3}$	=	significant wave height in ft for computing optimum gear ratio
DHP	$P_{D_{max}}$	=	maximum power delivered at propellers
RPM-P	N	=	propeller rpm required at $V_{K_{max}}$ and $H_{1/3}$
OPT.GEAR RATIO	$m_{g_{opt}}$	=	optimum gear ratio
		=	$\dfrac{\text{engine rpm at maximum power}}{\text{propeller rpm required at } V_{K_{max}} \text{ and } H_{1/3}}$

Page 9 -- Thrust at Maximum RPM of Prime Movers

GEARRATIO	m_g	=	gear ratio, input from Card 19 or optimum m_g computed by program
RPM	N_{max}	=	maximum rpm of propellers
		=	$N_{e_{max}} / m_g$
	n_{max}	=	Maximum rps of propellers = $N_{max}/60$
V-KT	V_K	=	Ship speed in knots, input from Card 7
SIGMA	σ	=	cavitation number
J	J_{max}	=	propeller advance coefficient at max. rpm
		=	$V_A / (n_{max} D)$
KT	K_T	=	propeller thrust coefficient at J_{max}
KQ	K_Q	=	propeller torque coefficient at J_{max}
EP	η_O	=	propeller efficiency at J_{max}
			K_T, K_Q, η_O generated from Subroutine PRINTP as function of J_{max} and σ
T-LB	T_{max}	=	maximum thrust in lb available at N_{max}
		=	$K_T \rho n_{max}^2 D^4 n_{pr}$
	C after T_{max}		indicates more than 10% back cavitation
	*after T_{max}		indicates limit due to cavitation
Q-FT.LB	Q_{max}	=	torque in ft-lb at N_{max}
		=	$K_Q \rho n_{max}^2 D^5 n_{pr}$
	*after Q_{max}		indicates that torque limit of prime movers is exceeded
DHP	P_D	=	power delivered at propellers = $2\pi Q_{max} n_{max}/550$

Page 9 -- Thrust at Torque Limits of Prime Movers

DHP	P_D'	=	developed horsepower
RPM	N'	=	propeller rpm
Q-FT.LB	Q'	=	developed torque

(DHP, RPM, Q-FT.LB: calculated from input points for engine characteristics-- See output Page 2)

	n'	=	propeller rps = $N'/60$
V-KT	V_K'	=	ship speed in knots at which $K_Q = Q'/(\rho n'D^5 npr)$ matches $J' = V_A'/(n'D)$ from propeller curves obtained by iteration and interpolation
SIGMA	σ'	=	Cavitation number at V_K'
J	J'	=	propeller advance coefficient at n' = $V_A'/(n'D)$
K_T	K_T	=	propeller thrust coefficient at J'
K_Q	K_Q	=	propeller torque coefficient at J'
EP	η_O	=	propeller efficiency at J'
			K_T, K_Q, η_O generated from Subroutine PRINTP as function J' and σ'
T-LB	T'	=	thrust in lb available= $K_T\rho(n')^2 D^4 n_{pr}$
Q-FT.LB	Q'	=	torque in ft-lb check = $K_Q\rho(n')^2 D^5 n_{pr}$
DHP	P_D'	=	developed horsepower check = $2\pi Q' n'/550$

Page 9 -- Speed-Power Limits

H13-FT	$H_{1/3}$	=	significant wave height in ft, input from Card 8
V-KT	$V_{K_{max}}$	=	ship speed in knots at which thrust required at $H_{1/3}$ (output page 6) reaches the thrust limit of the prime movers (output page 7) due to either rpm or torque restriction, whichever is lower

T-LB	T	=	total thrust in lb at $V_{K_{max}}$
	C after T		indicates more than 10% back cavitation
	* after T		indicates thrust limit due to cavitation
Q-FT.LB	Q	=	total torque in ft-lb at $V_{K_{max}}$
	* after Q indicates torque limit of prime movers		
RPM	N	=	propeller rpm at $V_{K_{max}}$
	# after N indicates rpm limit of prime movers		
DHP	P_D	=	total developed horsepower at $V_{K_{max}}$

Page 10 -- Habitability Limits

V-KT	V_K	=	ship speed in knots, input from Card 7
1.0G	1.0g	=	average 1/10 highest vertical accelerations representing the endurance limit of the crew for a maximum of 4 to 8 hours
1.5G	1.5g	=	average 1/10 highest vertical accelerations representing the endurance limit of the crew for 1 to 2 hours
H13-FT	$H_{1/3}$	=	significant wave height in ft. corresponding to habitability limit of 1.0 g (or 1.5g) -- interpolated from accelerations at location X_{acc} on output Page 6 Note: acceleration predicators are considered not valid for $H_{1/3} > 0.75\ B_{PX}$

NAME: SUBROUTINE PRCHAR

PURPOSE: Generate propeller open-water and cavitation characteristics. Select suitable propeller diameter, if not input

CALLING SEQUENCE: CALL PRCHAR

SUBPROGRAMS CALLED: OWKTQ, CAVKTQ, PRINTP, YINTX

INPUT:

DIN	D_{in}	=	propeller diameter in inches, from Card 20 If not input, a suitable diameter will be selected by this routine.
PD	P/D	=	propeller pitch ratio, from Card 20
EAR	EAR	=	expanded area ratio, from Card 20
Z	Z	=	number of blades, from Card 20
VADES	V_A	=	design speed of advance in ft/sec derived from design ship speed, indexed from Card 20
TDES	T	=	total thrust in lb required at design speed and wave height, indexed from Card 20
PDES	P_D	=	total design power at propellers derived from design brake power input on Card 20
PRN	n_{pr}	=	number of propellers, from Card 6

PROPELLER OPEN-WATER CHARACTERISTICS: See Subroutine OWKTQ

PROPELLER CAVITATION CHARACTERISTICS: See Subroutine CAVKTQ

SELECTION OF PROPELLER DIAMETER: (When D is not input)

DMIN	D_{min}	=	minimum diameter in inches based on 10% back cavitation criteria for adequate blade area of Gawn-Burrill type propellers
		=	$12\sqrt{T / [n_{pr} \rho V_A^2 (K_T/J^2)]}$
			where K_T/J^2 is derived from $\tau_c = 0.494\ \sigma_{0.7R}^{0.88}$ representing the Gawn-Burrill 10% cavitation line
DMAX	D_{max}	=	maximum diameter in inches based on maximum propeller efficiency
			same equation as above, with K_T/J^2 at point of maximum η_0
DIAM	D_i	=	array of diameters in increments of 5 inches from D_{min} to D_{max}
DHP	P_i	=	array of power requirements for above diameters
RPM	N_i	=	array of propeller rpm requirements for above diameters
DIN	D_{opt}	=	optimum diameter selected, rounded up to next full inch
	D_{opt}	=	D_{min} if power required $\leq$ design power
	D_{opt}		is interpolated from D_i array if design power is between requirements for D_{min} and D_{max}
	D_{opt}	=	D_{max} or D_{min}, whichever is larger, if both power requirements exceed design power

NAME:	SUBROUTINE OWKTQ
PURPOSE:	Calculate propeller open-water characteristics as function of pitch ratio, expanded area ratio, and number of blades from coefficients derived from Wageningen B-Screw Series.
REFERENCE:	Oosterveld and Van Oossanan, "Recent Development in Marine Propeller Hydrodynamics," Proceedings of the Netherlands Ship Model Basin 40th Anniversary (1972), and "Further Computer Analyzed Data of the Wageningen B-Screw Series", International Shipbuilding Progress, Vol. 22 (July 1975).
CALLING SEQUENCE:	CALL OWKTQ

INPUT:

PD	P/D	= propeller pitch/diameter ratio
EAR	EAR	= propeller expanded area ratio
Z	Z	= number of propeller blades

OUTPUT:

N	n_J	= number of J values generated -- max of 60
JT	J	= array of propeller advance coefficients in ascending order from (J=0.) to (J at K_T=0.) in increments of 0.025 if $P/D \leq 1.2$ in increments of 0.05 if $P/D > 1.2$
KT	K_T	= array of open-water thrust coefficients = f (P/D, EAR, Z, J)
KQ	K_Q	= array of open-water torque coefficients = f (P/D, EAR, Z, J)

K_T and K_Q developed from equations in above references. For Gawn-Burrill type propellers (IPROP=1) the equations are modified to produce slightly higher K_T and K_Q than the Wageningen B-Screw Series.

NAME: SUBROUTINE CAVKTQ

PURPOSE: Calculate propeller characteristics in cavitation regime as function of pitch ratio, expanded area ratio and cavitation number. Generate CALCOMP plots of K_T and K_Q versus J.

REFERENCE: Blount and Fox, "Design Considerations for Propellers in a Cavitating Environment," Marine Technology (Apr 1978)

CALLING SEQUENCE: CALL CAVKTQ

SUBPROGRAMS CALLED: TQMAX, CALCOMP Routines

INPUT:

IPROP	Control for type of propellers	= 1 for Gawn-Burrill type (flat face, segmental sections) = 2 for Newton-Rader types = 3 for Wageningen B-Screw (airfoil sections)
PD	P/D	= propeller pitch/diameter ratio
EAR	EAR	= propeller expanded area ratio
NJ	n_J	= number of J values input from open-water curves -- max. of 60
JT	J	= array of propeller advance coefficients
KTO	K_{T_O}	= corresponding array of propeller open-water thrust coefficients
KQO	K_{Q_O}	= corresponding array of propeller open-water torque coefficients
NS	n_s	= number of cavitation numbers -- max. of 8 -- at which propeller characteristics are to be computed and printed from this routine (if n_s = 0 only the constants are computed)
SIGMA	σ	= array of cavitation numbers
IPLOT	Control of CALCOMP plots	= 2 for plots of K_T and K_Q vs J at each σ (no plots done if IPLOT < 2)

GENERAL NOTATION FOR PROPELLERS:

V_A	= propeller speed of advance
n	= rate of revolution
D	= propeller diameter
T	= thrust
Q	= torque
ρ	= water density
P_O	= pressure at center of propeller = $p_A + p_H - p_V$
J	= advance coefficient = $V_A / (n\ D)$
K_T	= thrust coefficient = $T / (\rho\ n^2\ D^4)$
K_Q	= torque coefficient = $Q / (\rho\ n^2\ D^5)$
K_T/J^2	= thrust loading = $T / (\rho\ D^2 V_A{}^2)$
K_Q/J^2	= torque loading = $Q/(\rho\ D^3\ V_A{}^2)$
K_Q/J^3	= power loading = $Q\ n / (\rho\ D^2\ V_A{}^3)$
σ	= cavitation number based on advance velocity = $P_O / (1/2\ \rho V_A{}^2)$
$V_{0.7R}{}^2$	= velocity ^{2} at 0.7 radius of propeller = $V_A{}^2 + (0.7\pi\ nD)^2 = V_A{}^2(J^2+4.84)/J^2$
$\sigma_{0.7R}$	= cavitation number based on $V_{0.7R}$ = $P_O/(1/2\ \rho V_{0.7R}{}^2) = \sigma J^2/(J^2+4.84)$
Ap	= projected area of propeller = $(\pi\ D^2/4)$ EAR $(1.067-0.229\ P/D)$
τ_c	= thrust load coefficient = $T / (1/2\ \rho\ Ap\ V_{0.7R}{}^2)$ = $K_T / \left[1/2\ (Ap/D^2)\ (J^2+4.84)\right]$
Q_c	= torque load coefficient = $Q / (1/2\ \rho\ Ap\ V_{0.72R}{}^2)$ = $K_Q / \left[1/2\ (Ap/D^2)\ (J^2+4.84)\right]$

MAXIMUM THRUST AND TORQUE LOADS:

Blount and Fox (see reference) give equations for maximum thrust and torque load coefficients in a cavitating environment based on regression of experimental data for the three propeller series used herein.

τ_{c_m} = maximum thrust load coefficient
= $a\, \sigma_{0.7R}^{b}$ (transition region)
= τ_{c_x} (fully cavitating region)

Q_{c_m} = maximum torque load coefficient
= $c\, \sigma_{0.7R}^{d}$ (transition region)
= Q_{c_x} (fully cavitating region)

OUTPUT:

			IPROP
T1	a	= 1.2	1
	a	= 0.703 + 0.25 P/D	2
	a	= 1.27	3
T2	b	= 1.0	1
	b	= 0.65 + 0.1 P/D	2
	b	= 1.0	3
Q1	c	= 0.200 P/D	1
	c	= 0.240 P/D - 0.12	2
	c	= 0.247 P/D - 0.0167	3
Q2	d	= $0.70 + 0.31\ EAR^{0.9}$	1
	d	= 0.50 + 0.165 P/D	2
	d	= 1.04	3
TCX	τ_{c_x}	= 0.0725 P/D - 0.0340 EAR	1
	τ_{c_x}	= 0.0833 P/D - 0.0142 EAR	2
	τ_{c_x}	= 0.0	3
QCX	Q_{c_x}	= $[0.0185\,(P/D)^2 - 0.0166\ P/D + 0.00594] / EAR^{1/3}$	1
	Q_{c_x}	= $0.0335\ P/D - 0.024\ EAR^{1/2}$	2
	Q_{c_x}	= 0.0	3
RMAX	k	= 0.8	

Since full-scale trial data (see Figures 5 and 6 of reference) indicates actual thrust and torque in the transition region less than the maximums derived from the propeller series data, the factor k is applied to τ_{c_m} and Q_{c_m} in the transition region. The factor k is not applied to τ_{c_x} and Q_{c_x}.

APD2	$A_p/D^2/2$	=	Constant for calculation of τ_c and Q_c
J	J	=	advance coefficient from input array
OPEN WATER KT KQ	K_{T_o} K_{Q_o}	=	input values of open-water thrust and torque coefficients
SIGMA	σ	=	cavitation number from input array
KT	K_T	=	thrust coefficient as f (J, σ)
		=	K_{T_o} or K_{T_m}, whichever is smaller
	K_{T_m}	=	τ_{c_m} (1/2 A_p/D^2) (J^2 +4.84)
	τ_{c_m}	=	(k a $\sigma_{0.7R}{}^b$) or (τ_{c_x}), whichever is greater
LC		=	1 character **identifier** for propeller cavitation C indicates more than 10% back cavitation for Gawn props: $\tau_c > 0.494\ \sigma_{0.7R}{}^{0.88}$ * indicates thrust limit due to cavitation $K_T = K_{T_m}$
KQ	K_Q	=	torque coefficient as f (J, σ)
		=	K_{Q_o} or K_{Q_m}, whichever is smaller
	K_{Q_m}	=	Q_{c_m} (1/2 A_p/D^2) (J^2 + 4.84)
	Q_{c_m}	=	(k c $\sigma_{0.7R}{}^d$) or (Q_{c_x}), whichever is greater
			K_{T_m} and K_{Q_m} generated by Function TQMAX

CALCOMP PLOTS: If IPLOT=2, open-water K_T and K_Q as well as K_T and K_Q representing the transition region and fully cavitating region at each σ are plotted as a function of J.

NAME: FUNCTION TQMAX

PURPOSE: Calculate maximum thrust or torque coefficient in a cavitating environment as function of cavitation number and advance coefficient

CALLING SEQUENCE: X = TQMAX (SIGMA, JT, ITQ)

INPUT:

SIGMA	σ	=	cavitation number
JT	J	=	advance coefficient
ITQ	i	=	1 if maximum thrust coefficient required
	i	=	2 if maximum torque coefficient required

Variables: a, b, c, d, τ_{c_x}, Q_{c_x}, k, $1/2\ A_p/D^2$ generated by Subroutine CAVKTQ

OUTPUT:

TQMAX K_{T_m} or K_{Q_m} depending on value of i

τ_{c_m} = maximum thrust load coefficient
= $k\ a\ \sigma_{0.7R}^{\ b}$, or τ_{c_x} if greater

K_{T_m} = $\tau_{c_m}\ (1/2\ Ap/D^2)\ (J^2+4.84)$

Q_{c_m} = maximum torque load coefficient
= $k\ c\ \sigma_{0.7R}^{\ d}$, or Q_{c_x} if greater

K_{Q_m} = $Q_{c_m}\ (1/2\ A_p/D^2)\ (J^2+4.84)$

NAME: SUBROUTINE PRINTP

PURPOSE: Interpolate for propeller performance at specified value of (1) advance coefficient J, (2) thrust loading K_T/J^2, (3) torque loading, K_Q/J^2, or (4) power loading K_Q/J^3.

CALLING SEQUENCE: CALL PRINTP (IP, PCOEF, SIGMA)

SUBPROGRAMS: TQMAX, YINTE

INPUT:

IP	Option	=	1, 2, 3, or 4
PCOEF		=	input propeller coefficient, dependent on value of IP
	J_T	=	advance coefficient, input if IP=1
	K_T/J^2	=	thrust loading, input if IP=2
	K_Q/J^2	=	torque loading, input if IP=3
	K_Q/J^3	=	power loading, input if IP=4
SIGMA	σ	=	cavitation number
NJ	n_J	=	number of J values defining propeller characteristics
JT	J	=	array of advance coefficient, in ascending order
KT	K_{T_o}	=	array of open-water thurst coefficients
KQ	K_{Q_o}	=	array of open-water torque coefficients

PERFORMANCE AT SPECIFIC J:

JTP	J_T	=	input advance coefficient
KTP	K_T	=	thrust coefficient at J_T
		=	open-water thrust coefficient interpolated from input array of K_{T_o} versus J, or maximum thrust coefficient in cavitating regime K_{T_m} calculated by Function TQMAX, whichever is smaller.
KQP	K_Q	=	torque coefficient at J_T
		=	open-water value interpolated from K_{Q_o} vs J, or maximum cavitation value K_{Q_m} calculated from TQMAX, whichever is smaller

PERFORMANCE AT SPECIFIC LOADING:

PLOG	$\ln(K_T/J^2)$	if IP=2	natural log of input loading coefficient
	$\ln(K_Q/J^2)$	if IP=3	
	$\ln(K_Q/J^3)$	if IP=4	
XLOG	$\ln(K_{T_o}/J_o^2)$	if IP=2	array of natural logs of open-water loading coefficient at J value from input array
	$\ln(K_{Q_o}/J_o^2)$	if IP=3	
	$\ln(K_{Q_o}/J_o^3)$	if IP=4	

JTP $\quad J_{T_o}$ = open-water advance coefficient interpolated from array of open-water loading coefficients versus J at the specific loading required (logs are used because of the rapid change of loading coefficient at low J's)

If J_{T_o} is in non-cavitating region ($K_{T_o} < K_{T_m}$)

KTP	K_T	thrust and torque coefficients at J_{T_o}
KQP	K_Q	interplated from arrays of K_{T_o} and K_{Q_o} vs J

If J_{T_o} is in cavitating region ($K_{T_o} > K_{T_m}$)

XLOG	$\ln(K_{T_m}/J^2)$	if IP=2	array of natural logs of loading coefficients based on K_{T_m} or K_{Q_m} as function J
	$\ln(K_{Q_m}/J^2)$	if IP=3	
	$\ln(K_{Q_m}/J^3)$	if IP=4	

JTP $\quad J_{T_m}$ = advance coefficient interpolated from array of cavitation loading coefficients vs J at the specific loading required

KTP	KT	maximum cavitation thrust and torque coefficients at J_{T_m} calculated from TQMAX
KQP	KQ	

OUTPUT:

JTP	J_T	= final advance coefficient	at propeller performance point specified by PCOEF and SIGMA
KTP	K_T	= final thrust coefficient	
KQP	K_Q	= final torque coefficient	
EP	η_O	= propeller efficiency = $J_T K_T/(2\pi K_Q)$	

TAUC	τ_c	=	thrust load coefficient
		=	$K_T \,/\, \left[\frac{1}{2}(A_p/D^2)\ (J^2+4.84)\right]$
SIG7	$\sigma_{0.7R}$	=	cavitation number based on velocity at 0.7 radius of propeller
		=	$\sigma\, J^2/\,(J^2+4.84)$ $\qquad 4.84=(0.7\pi)^2$
XSIG7	$4.94\ \sigma_{0.7R}^{0.88}$	=	term representing 10% back cavitation line for Gawn-Burrill propeller series
LT		=	1 character identifier for propeller cavitation

* indicates thrust limit due to cavitation:
$K_T = K_{T_m}$

C indicates more than 10% back cavitation for Gawn-Burrill propellers, but less than thrust limit cavitation

$$\tau_c > 0.494\ \sigma_{0.7R}^{0.88}$$

NAME:	SUBROUTINE TPLOT
PURPOSE:	Generate CALCOMP plots of thrust versus speed for (1) thrust required in various sea states (2) thrust limit at maximum rpm of prime movers (3) thrust at torque limit of prime movers with one or more gear ratios (4) thrust at 10% back cavitation, if IPROP = 1
CALLING SEQUENCE:	CALL TPLOT
SUBPROGRAMS	CALCOMP Routines, FACTOR, PLOT, AXIS, SYMBOL, NUMBER, FLINE, DASHL

INPUT:

TITLE		= identification to be printed at top of graph 80 characters maximum
VKT	V_K	= array of ship speeds in knots
H13	$H_{1/3}$	= array of significant wave heights in ft.
NV	n_V	= number of speeds -- maximum of 20
NWH	n_H	= number of wave heights -- maximum of 5
NE	n_e	= number of points defining torque limits of prime movers -- maximum of 10
NGR	n_g	= number of gear ratios -- maximum of 4
T	T	= matrix of values for thrust required as function of V_K and $H_{1/3}$
TC	T_c	= array of thrust values representing 10% back cavitaiton, if IPROP = 1
TN	T_N	= array of thrust values at maximum rpm of prime movers
VQ	V_{K_Q}	= array of speeds in knots at which torque limits are defined
TQ	T_Q	= array of thrust values corresponding to torque limits of prime movers
GR	m_g	= array of gear ratios

OUTPUT: SUBROUTINE TPLOT

X-axes	Ship speed V in knots Ship speed V in m/sec
Y-axes	Thrust in lb Thrust in N
Curves	(1) Thrust required at each wave height $H_{1/3}$ (2) Thrust at engine rpm limit, for each gear ratio (3) Thrust at engine torque limit, for each gear ratio (4) Thrust representing 10% back cavitation (dash line)

Intersection of Curve (1) and the lower of curves (2) and (3) represents the maximum speed obtainable at each wave height and gear ratio.

NAME	SUBROUTINE HPLOT
PURPOSE:	Generate CALCOMP plots of significant wave height versus speed corresponding to (1) endurance limit of crew for 4 to 8 hours operation (2) endurance limit of crew for 1 to 2 hours operation (3) power limit of propulsion system for 1 or more gear ratios
CALLING SEQUENCE:	CALL HPLOT
SUBPROGRAMS:	CALCOMP Routines FACTOR, PLOT, AXIS, SYMBOL, NUMBER, FLINE

INPUT:

TITLE		= identification to be printed at top of graph maximum of 80 characters
VKT	V_K	= array of ship speeds in knots
H13	$H_{1/3}$	= array of significant wave heights in ft
NV	n_V	= number of speeds -- maximum of 20
NWH	n_H	= number of wave heights -- maximum of 5
NGR	n_g	= number of gear ratios -- maximum of 4
H10G	$H_{1.0g}$	= array of significant wave heights as function of V_K corresponding to average 1/10 highest vertical accelerations of 1.0g
H15G	$H_{1.5g}$	= array of significant wave heights as function of V_K corresponding to vertical acceleration of 1.5g
VKTW	$V_{K_{max}}$	= array of maximum ship speeds in knots as function of $H_{1/3}$, derived from intersection of required thrust at each wave height with thrust curve at engine rpm or torque limit, whichever is lower
XACC	X_{acc}	= distance forward of transom in ft at which accelerations have been computed
GR	m_g	= array of gear ratios

OUTPUT:

X-axes	Ship speed V in knots Ship speed V in m/sec
Y-axes	Significant wave height $H_{1/3}$ in ft Significant wave height $H_{1/3}$ in m
Curves	Wave height envelopes representing average 1/10 heighest vertical accelerations of (1) 1.0 g -- habitability limit for 4 to 8 hours (2) 1.5 g -- habitability limit for 1 to 2 hours (3), (4), etc. Envelopes of maximum speed versus wave height due to power limit of the propulsion system, for 1 to 4 gear ratios

NAME: SUBROUTINE PRCOEF

PURPOSE: Estimate propulsion coefficients for planing hull with propellers on inclined shafts

REFERENCE: Blount, D.L. and D.L. Fox, "Small Craft Power Predictions," Western Gulf Section of the Society of Naval Architects and Marine Engineers (Feb 1975)

CALLING SEQUENCE: CALL PRCOEF (FNV, TDF, ADF, TWF)

SUBPROGRAMS: MINP, YINTE

INPUT:

FNV $F_{n\nabla}$ = speed-displacement coefficient = $V/(g\ \nabla^{1/3})^{1/2}$

OUTPUT:

TDF 1-t = thrust deduction factor

$$= \frac{\text{total horizontal resistance } (R_T)}{\text{total shaft-line thrust } (T)}$$

ADF η_a = appendage drag factor

$$= \frac{\text{resistance of bare hull } (R_b)}{\text{resistance of appendaged hull } (R_a)}$$

TWF 1-w = thrust wake factor = torque wake factor

PROCEDURE: 1-t, 1-w, and η_a interpolated from following table of values at input value of $F_{n\nabla}$. The tabulated data represent mean values from a bandwidth of data collected for numerous twin-screw planing craft and reported in above reference.

$F_{n\nabla}$	1-t	1-w	η_a
0.5	0.92	1.05	0.951
1.0	0.92	1.06	0.948
1.5	0.92	1.04	0.942
2.0	0.92	0.99	0.934
2.5	0.92	0.97	0.925
3.0	0.92	0.975	0.913
3.5	0.92	0.98	0.900
4.0	0.92	0.975	0.885

NAME: SUBROUTINE PHRES

PURPOSE: Estimate the bare-hull, smooth-water resistance of a hard-chine planing hull from synthesis of Series 62 and 65 experimental data

REFERENCE: Hubble, E.N., "Resistance of Hard-Chine, Stepless Planing Craft with Systematic Variation of Hull Form, Longitudinal Center of Gravity, and Loading," DTNSRDC Report 4307 (Apr 1974).
Figures 9 and 10 of DTNSRDC Report SPD-0840-01 (Dec 1978, Revised Aug 1979)

CALLING SEQUENCE: CALL PHRES (DLBS, FNV, SLR, DCF, SDF, RHO2, VIS, RLBS)

SUBPROGRAMS: DISCOT, YINTX, C1DSF

INPUT:

DLBS — Δ = ship displacement in lb

FNV — $F_{n\nabla}$ = speed-displacement coefficient $(V/(g/\nabla^{1/3})^{1/2}$

SLR — $L_p/\nabla^{1/3}$ = slenderness ratio

DCF — ΔC_F = correlation allowance; may be 0.0

SDF — SDF = 0.0 corresponds to mean resistance-weight R/W curves derived from Series 62 and 65 data
= 1.645 corresponds to minimum R/W curves

can be varied to approximate R/W for a particular hull form from model experiments

RHO2 — $\rho/2$ = 0.5 x water density in lb x sec^2/ft^4

VIS — ν = water viscosity in ft^2/sec

OUTPUT:

RLBS — R_b = bare-hull, smooth-water resistance in lb
= (mean R/W - SDF x σ) x Δ
σ = standard deviation of Series 62-65 data from mean R/W

PROCEDURE:

XFNV array — Tabulated values of $F_{n\nabla}$ from 0.0 to 4.0

ZSLR array — Tabulated values of $L_p/\nabla^{1/3}$ from 4.0 to 10.0

YRWM matrix	Tabulated values of mean R/W as $f(F_{n\nabla}, L_p/\nabla^{1/3})$ for 100,000-lb planing craft derived from Series 62 and 65 experimental data. See Table 1.		
YWSR matrix	Tabulated values of mean wetted area coefficients $S/\nabla^{2/3}$ from Series 62 and 65 hulls. See Table 2.		
SD array	Tabulated values of standard deviation σ as $f(F_{n\nabla})$ See Table 1.		
RWM	R/W for 100,000-lb planing craft interpolated from YRWM matrix of mean R/W values at input $F_{n\nabla}$ and $L_p/\nabla^{1/3}$		
WSR	$S/\nabla^{2/3}$ interpolated from YWSR matrix at input $F_{n\nabla}$ and $L_p/\nabla^{1/3}$		
	Subroutine DISCOT used for the double interpolation		
SDM	σ interpolated from SD array at input $F_{n\nabla}$		
	Function YINTX used for single interpolation		
RWM	$(R/W)_m$	=	corrected R/W for 100,000-lb planing craft = (mean R/W interpolated) - (SDF x σ)
DLBM	Δ_m	=	displacement of 100,000-lb planing craft
XL	λ	=	linear ratio of actual ship to 100,000-lb = $(\Delta/\Delta_m)^{1/3}$
VFPSM	V_m	=	speed of 100,000-lb craft in ft/sec = (input $F_{n\nabla}$) x 19.32
VFPSS	V_s	=	speed of actual ship in ft/sec = $V_m \lambda^{1/2}$
PLM	L_m	=	length of 100,000-lb craft in ft = 11.6014 (input $L_p/\nabla^{1/3}$)
PLS	L_s	=	length of actual ship in ft = $L_m \lambda$
REM	Rn_m	=	Reynolds number of 100,000-lb craft = $V_m L_m/\nu_m$
RES	Rn_s	=	Reynolds number of actual ship = $V_s L_s/\nu_s$
CFM	C_{F_m}	=	Schoenherr frictional resistance coefficient for 100,000-lb craft

CFS	C_{F_s}	=	Schoenherr frictional resistance coefficient for actual ship Function C1DSF used to obtain Schoenherr frictional resistance coefficients
SM	S_m	=	wetted area of 100,000-lb craft in ft^2
		=	$134.5925\ S/\nabla^{2/3}$
SS	S_s	=	wetted area of actual ship in $ft^2 = S_m\ \lambda^2$
RM	R_m	=	resistance of 100,000-lb craft in lb
		=	$(R/W)_m\ \Delta_m$
CTM	C_{T_m}	=	total resistance coefficient of 100,000-lb craft
		=	$R_m/(V_m^2\ S_m\ \rho_m/2)$
CR	C_R	=	residual resistance coefficient = $C_{T_m} - C_{F_m}$
CTS	C_{T_s}	=	total resistance coefficient of actual ship
		=	$C_{F_s} + C_R + \Delta C_F$
VIS	ν_s	=	kinematic viscosity for actual ship
VISM	ν_m	=	kinematic viscosity for tabulated data = 1.2817×10^{-5}
RHO2	$\rho_s/2$	=	1/2 water density for actual ship
RHO2M	$\rho_m/2$	=	1/2 water density for tabulated data
		=	1.9905/2
RLBS	R_b	=	resistance of actual ship in lb
		=	$C_{T_s}\ V_s^2\ S_s\ \rho_s/2$

NAME: SUBROUTINE SAVIT

PURPOSE: Estimate the bare-hull, smooth-water resistance and trim for a hard-chine planing hull using Savitsky's equations for prismatic planing surfaces

CALLING SEQUENCE: CALL SAVIT (DISPL, LCG, VCG, VFPS, BEAM, BETA, TANB, COSB, SINB, HW, WDCST, RHO, VIS, AG, DELCF, R, TD, NT, CLM, GDB)

SUBPROGRAM: CIDSF

INPUT:

DISPL	Δ	= ship displacement in lb
LCG	$\overline{AG}$	= distance of center of gravity CG forward of transom in ft
VCG	$\overline{KG}$	= distance of CG above baseline in ft
VFPS	V	= speed in ft/sec
BEAM	B	= beam in ft = maximum chine beam B_{PX}
BETA	β	= deadrise angle in degrees = deadrise at midships β_m
TANB	$\tan\beta$	
COSB	$\cos\beta$	
SINB	$\sin\beta$	
HW	H_W	= height of center of wind drag above baseline in ft
WDCST	C_{D_W}'	= horizontal wind force in lb /V^2
RHO	ρ	= water density in lb x sec^2/ft^4
VIS	ν	= kinematic viscosity of water in ft^2/sec
AG	g	= acceleration of gravity in ft/sec^2
DELCF	ΔC_F	= correlation allowance; may be 0

OUTPUT:

R	R_b	= bare hull, smooth-water resistance in lb

TD	τ	= trim angle in degrees
NT	Number of iterations to obtain trim angle	
CLM	λ	= mean wetted length-beam ratio L_m/B
GDB	$\overline{AP}$	= longitudinal center of pressure, distance forward of transom, in ft

PROCEDURE:

TD	τ	= trim angle of planing surface from horizontal in deg first approximation of $\tau = 4$ deg
CV	C_V	= speed coefficient = $V/(gB)^{1/2}$
CLM	λ	= mean wetted length-beam ratio = $L_m/B = (L_K + L_C)/2B$
CLO	C_{L_o}	= lift coefficient for flat surface = $\tau^{1.1}(0.012\ \lambda^{1/2} + 0.0055\ \lambda^{5/2}/C_V{}^2)$
CLB	C_{L_β}	= lift coefficient for deadrise surface = $\Delta/[V^2\ B^2\rho/2] = C_{L_o} - 0.0065\ C_{L_o}{}^{0.6}$ C_{L_o} and obtained by Newton-Raphson iteration first approximations: $C_{L_o} = 0.085$; $\lambda = 1.5$
XK	L_K	= wetted keel length in ft = $\beta[\lambda + \tan\beta\ /2\pi\ \tan\tau\ )]$
XC	L_C	= wetted chine length in ft = $2B\lambda - L_K$ $L_K - L_C = (B\tan\beta)/(\pi\tan\tau)$
GDB	AP	= longitudinal center of pressure forward of transom in ft = $B\ \lambda[0.75 - 1/(5.21\ C_V{}^2\ /\ \lambda^2 + 2.39)]$
CLD	C_{L_d}	= dynamic component of lift coefficient = $0.012\ \lambda^{1/2}\ \tau^{1.1}$
VM	V_m	= mean velocity over planning surface in ft/sec = $V\ \left[1-(C_{L_d} - 0.0065\ \beta\ C_{L_d}{}^{0.6})/(\lambda\ \cos\tau\ )\right]^{1/2}$
RE	R_n	= Reynolds number for planing surface = $V_m\ B\ \lambda\ /\ \nu$

CF	$C_F + \Delta C_F$	= Schoenherr frictional resistance coeffcient as $f(R_n)$ plus correction allowance
DFX	D_F	= viscous force due to wetted surface, parallel to the planing surface, in lb = $(C_F+\Delta C_F)\ (\rho/2\ (V_m{}^2)\ \ (B^2\ \ \lambda/\cos\beta\ )$
CK	C_K	= $1.5708\ (1 - 0.1788\ \tan^2\beta\cos\beta - 0.09646\ \tan\beta\ \sin^2\beta)$
CK1	C_{K_1}	= $C_K\ \tan\tau\ /\sin\beta$
A1	a_1	= $\dfrac{\left[\sin^2\tau(1-2C_K) + C_K{}^2\tan^2\tau(1/\sin^2\beta-\sin^2\tau)\right]^{1/2}}{\cos\tau + C_K\tan\tau\ \sin\tau}$
TAN	$\tan\phi$	= $(a_1+C_{K_1}\ )/(1-a_1\ C_{K_1})$
THETA	θ	= angle between outer spray edge and keel in radians = $\arctan(\tan\phi\ \cos\beta\ )$
DLM	$\Delta\lambda$	= effective increase in length-beam ratio due to spray = $[\tan\beta\ (\ \pi\ \tan\tau)] - 1/(\ 2\ \tan\theta\ )\ /(2\ \cos\theta\ )$
RE	R_{n_S}	= Reynolds number of spray = $VB\ /(3\cos\beta\ \sin\ \theta\ )\ /\nu$
CF	C_{F_S}	= Schoenherr frictional resistance coefficient for spray drag
DSX	D_S	= viscous force due to spray drag, parallel to the planing surface, in lb = $C_{F_S}\ (\rho/2)\ V^2)\ (B^2\Delta\lambda\ /\ \cos\beta\ )$
DWX	D_W	= component of wind drag parallel to planing surface in lb = $C_{D_W}{}'\ V^2/\cos\tau$
DTX	D_T	= total drag force parallel to planing surface in lb = $D_F + D_S + D_W$
PDBX	P_T	= total pressure force perpendicular to surface in lb = $\Delta/\cos\tau + D_T\ \tan\tau$

EDB	e_p	= moment arm from center of pressure to CG in ft
		= $\overline{AG} - \overline{AP}$
FF	f_F	= moment arm from center of viscous force to CG in ft
		= $\overline{KG}$ - (B tan β /4)
FW	f_W	= moment arm from center of wind drag to CG in ft
		= $\overline{KG} - H_W$
RMT	ΣM	= sum of moments about CG in ft-lb
		= $P_T e_P + (D_F+D_S) f_F + D_W f_W$
	Iterate with small changes in τ until $\Sigma M \leq 0.001\Delta$	
NT	Number of iterations required to obtain equilibrium trim; maximum of 15 iterations	
R	R	= net horizontal resistance force in lb
		= $D_T \cos\tau + P_T \sin\tau$

NAME: FUNCTION C1DSF

PURPOSE: Calculate Schoenherr frictional resistance coefficient

CALLING SEQUENCE: CF = C1DSF (XN1RE)

INPUT:

XN1RE — R_n = Reynolds number = $V\,L\,/\,\nu$

OUTPUT:

C1DSF — C_F = Schoenherr frictional resistance coefficient

PROCEDURE: Iteration with Newton-Raphson method
Schoenherr formula: $0.242\,/\sqrt{C_F} = \log_{10} R_n\,C_F$

NAME:	FUNCTION SIMPUN
PURPOSE:	Numerical integration of area under curve defined by set of (x,y) points at either equal or unequal intervals
CALLING SEQUENCE:	AREA = SIMPUN (X, Y, N)
INPUT:	
X array	Table of x values--independent variable x values must be in ascending order
Y array	Table of y values--dependent variable
N	Number of (x,y) values
OUTPUT:	
SIMPUN	Area under curve $\approx \int y\, dx$

NAME:	SUBROUTINE DISCOT
PURPOSE:	Single or double interpolation for continuous or discontinuous function using Lagrange's formula
CALLING SEQUENCE:	CALL DISCOT (XA, ZA, TABX, TABY, TABZ, NC, NY, NZ, ANS)
SUBPROGRAMS CALLED:	UNS, DISSER, LAGRAN These subroutines are concerned with the interpolation, and are not documented separately
INPUT:	
XA	x value (first independent variable) for interpolated point
ZA	z value (second independent variable) for interpolated point Same as x value for single-line function interpolation
TABX array	Table of x values--first independent variable
TABY array	Table of y values--dependent variable
TABZ array	Table of z values--second independent variable
NC	Three digit control integer with ± sign Use + sign if NX = NY/NZ = points in X array Use - sign if NX = NY Use 1 in hundreds position for no extrapolation above maximum Z Use 0 in hundreds position for extrapolation above maximum Z Use 1-7 in tens position for degree of interpolation desired in X direction Use 1-7 in units position for degree of interpolation desired in Z direction
NY	Number of points in y array
NZ	Number of points in z array
OUTPUT:	
ANS	y value (dependent variable) interpolated at x, z

DISCOT is a "standard" routine used at DTNSRDC. Consult User Services Branch of the Computation, Mathematics and Logistics Department for additional information.

NAME: FUNCTION MINP

PURPOSE: Select index of minimum x value to be used for Lagrange interpolation, from an array of x values greater than required

CALLING SEQUENCE: I = MINP (M, N, XA, X)

INPUT:

M	m = number of points required for interpolation of degree m-1
N	n = total number of points in x array $\geq$ m
XA	x value to be used for interpolation
X array	Table of x values, must be in ascending order, but need not be equally spaced

OUTPUT:

MINP	Index of minimum x value from the array to be used by FUNCTION YINTE for Lagrange interpolation of degree m-1

SAMPLE PROGRAM USING FUNCTIONS MINP AND YINTE:

```
DIMENSION X(10), Y(10)
N  = 10
M  = 4
READ (5, 10) (X(J), J=1, N), (Y(J), J=1, N), XA
I  = MINP (M, N, XA, X)
YA = YINTE (XA, X(I), Y(I), M)
```

ALTERNATE PROGRAM USING FUNCTION YINTX:

```
DIMENSION X(10), Y(10)
N  = 10
M  = 4
READ (5, 10) (X(J), J=1, N), (Y(J), J=1, N), XA
YA = YINTX (XA, X, Y, M, N)
```

The result from either program is the same. In either case, only the M points closest to XA are considered in the interpolation formula. The first combination should be used whenever several dependent variables are to be interpolated at some value of the independent variable, since MINP need only be called once. FUNCTION YINTE may be used alone whenever N = M.

NAME: FUNCTION YINTE

PURPOSE: Single interpolation of degree n-1 for function represented by n (x,y) points using Lagrange's formula

CALLING SEQUENCE: YA = YINTE (XA, X, Y, N)

INPUT:

XA	x value (independent variable) for interpolated point
X array	Table of x values--independent variable
	x values can be in either ascending or descending order and do not need to be equally spaced
Y array	Table of y values--dependent variable
N	n = number of (x,y) values defining the function

OUTPUT:

YINTE	Interpolated y value (dependent variable) derived from Lagrange formula of degree n-1
	For example, when n = 4, cubic interpolation is performed

Lagrange's Interpolation Formula

$$y = \frac{(x-x_1)\ (x-x_2)\ \dots\ (x-x_n)}{(x_0-x_1)\ (x_0-x_2)\ \dots\ (x_0-x_n)}\, y_0$$

$$+ \frac{(x-x_0)\ (x-x_2)\ \dots\ (x-x_n)}{(x_1-x_0)\ (x_1-x_2)\ \dots\ (x_1-x_n)}\, y_1$$

$$+ \frac{(x-x_0)\ (x-x_1)\ (x-x_3)\ \dots\ (x-x_n)}{(x_2-x_0)\ (x_2-x_1)\ (x_2-x_3)\ \dots\ (x_2-x_n)}\, y_2 + \dots$$

$$+ \frac{(x-x_0)\ (x-x_1)\ (x-x_2)\ \dots\ (x-x_{n-1})}{(x_n-x_0)\ (x_n-x_1)\ (x_n-x_2)\ \dots\ (x_n-x_{n-1})}\, y_n$$

NAME:	FUNCTION YINTX
PURPOSE:	Single interpolation of degree m-1 for function represented by n (x,y) points using Lagrange's formula. If n > m, only the m closest points are considered in the interpolation formula
CALLING SEQUENCE:	YA = YINTX (XA, X, Y, M, N)
INPUT:	
XA	x value (independent variable) for interpolated point
X array	Table of x values--independent variable x values must be in ascending order, but need not be equally spaced
Y array	Table of y values--dependent variable
M	m = number of (x,y) values considered for the interpolation process of degree m-1
N	n = total number of (x,y) values $\geq$ m
OUTPUT:	
YINTX	Interpolated y value (dependent variable) derived from Lagrange formula of degree m-1
	FUNCTION YINTX may be used instead of FUNCTION MINP and FUNCTION YINTE together
	See Sample Programs using these three functions

APPENDIX B

SAMPLE INPUT AND OUTPUT FOR PHPRIM

```
CHNHPRR.CM77000.T200.MT1.P4.                                  1524. N.HUBBLE. EXT.71611
CHARGE.CHNH.LCLCU150-1.
REQUEST.TAPE8.*Q.
VSN(TAPE7=CA0553)
REQUEST.TAPE7.HI.RING.
MAP(OFF)
ATTACH.PHPRLMLGOJULY80.ID=CHNH.
ATTACH.CALC936.
ATTACH.CALCFN.
LDSET(LIB=CALC936)
LDSET(LIB=CALCFN)
PHPRLML.
COPYSBF.TAPE8.OUTPUT.
REWIND.TAPE8.
ROUTE.TAPE8.DC=PU.TID=C.
ROUTE.OUTPUT.TID=C.FC=HH.

  1
PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES
   65.0     60.0     15.0      2.0   80000.     20.0     24.0      8.0     45.0      2.5
   600.    2300.     1.00     1.02
 1.9905   1.2817   32.174      0.0     1.65
 14    5   2   10   1    1   1    1   1    1   0    1
    6.0      8.0     10.0     12.0     14.0     16.0     18.0     20.0     22.0     24.0
   26.0     28.0     30.0     32.0
    0.0      1.0      3.0      5.0      8.0
   350.     387.     423.     455.     485.     515.     542.     565.     585.     600.
  1400.    1500.    1600.    1700.    1800.    1900.    2000.    2100.    2200.    2300.
  2    9
    0.0      2.0
    0.0      0.6      0.7      0.7      3.0     600.       9.       4.
    0.0      0.7      0.7      0.7      3.0     600.       9.       4.
    0.0      0.8      0.7      0.7      3.0     600.       9.       4.
    0.0      0.9      0.7      0.7      3.0     600.       9.       4.
    0.0      1.0      0.7      0.7      3.0     600.       9.       4.
    0.0      1.1      0.7      0.7      3.0     600.       9.       4.
    0.0      1.2      0.7      0.7      3.0     600.       9.       4.
    0.0      1.3      0.7      0.7      3.0     600.       9.       4.
    0.0      1.4      0.7      0.7      3.0     600.       9.       4.
 END OF FILE
```

SAMPLE INPUT FOR PROGRAM PHPRLM

```
ECHO OF INPUT DATA      CASE  1

PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES
     65.00     60.00     15.00      2.00  80000.00     20.00     24.00      3.00     45.00      2.50
    600.00   2300.00      1.00      1.02
    1.9905    1.2817   32.1740    0.0300    1.6500
   14    5    2   10    1    1    1    1    1    1    0    1
      6.00      8.00     10.00     12.00     14.00     16.00     18.00     26.00     22.00     24.00
     26.00     28.00     30.00     32.00
      0.00      1.00      3.00      5.00      8.00
    350.00    387.00    423.00    455.00    485.00    515.00    542.00    565.00    585.00    600.00
   1400.00   1500.00   1600.00   1700.00   1800.00   1900.00   2000.00   2100.00   2200.00   2300.00
    2    9
      0.00      2.00
```

SAMPLE OUTPUT PAGE 1

PLANING HULL WITH PROPELLERS PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

CHARACTERISTICS OF PRIME MOVERS

2 DIESELS MAX.BHP PER ENGINE = 600.0 MAX.ENGINE RPM = 2300.0 BHP/SHP = 1.00 SHP/DHP = 1.02

BHP PER ENGINE	ENGINE RPM	TOTAL DHP	GEAR RATIO = 1.00		GEAR RATIO = 2.00		GEAR RATIO = 0.00		GEAR RATIO = 0.00	
			PROP.RPM	Q-FT.LB	PROP.RPM	Q-FT.LB	PROP.RPM	Q-FT.LB	PROP.RPM	Q-FT.LB
350.0	1400.0	686.3	1400.0	2574.6	700.0	5149.1				
387.0	1500.0	758.8	1500.0	2656.9	750.0	5313.9				
423.0	1600.0	829.4	1600.0	2722.6	800.0	5445.2				
455.0	1700.0	892.2	1700.0	2756.3	850.0	5512.6				
485.0	1800.0	951.0	1800.0	2774.8	900.0	5549.6				
515.0	1900.0	1009.8	1900.0	2791.4	950.0	5582.7				
542.0	2000.0	1062.7	2000.0	2790.8	1000.0	5581.6				
565.0	2100.0	1107.8	2100.0	2770.7	1050.0	5541.4				
585.0	2200.0	1147.1	2200.0	2738.4	1100.0	5476.8				
600.0	2300.0	1176.5	2300.0	2686.5	1150.0	5373.0				

SAMPLE OUTPUT PAGE 2

PLANING HULL WITH PROPELLERS   PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

LOA-FT	LP-FT	BPX-FT	HT-FT	DISPL-LB	BETA-DEG	LCG-FT	VCG-FT	XACC-FT	C-LOAD	LP/V13	LP/BPX	D-IN	P/D	EAR
65.00	60.00	15.00	2.00	80000.	20.00	24.00	8.00	45.00	.370	5.57	4.00	0.0	0.00	0.000

V-KT	V-LOA	FNV	SIGMA	1-T	1-W	EA	RB/W	RA/W	EHPB	EHPA
6.00	.74	.54	20.11	.920	1.052	.951	0.0000	0.0000	0.	0.
8.00	.99	.73	11.18	.920	1.058	.950	.0078	.0082	15.	16.
10.00	1.24	.91	7.13	.920	1.060	.949	.0287	.0303	71.	74.
12.00	1.49	1.09	4.97	.920	1.059	.947	.0549	.0580	162.	171.
14.00	1.74	1.27	3.69	.920	1.053	.945	.0776	.0822	267.	282.
16.00	1.98	1.45	2.88	.920	1.043	.943	.0866	.0918	340.	361.
18.00	2.23	1.63	2.34	.920	1.027	.940	.0930	.0989	411.	437.
20.00	2.48	1.81	1.97	.920	1.008	.937	.0997	.1064	489.	522.
22.00	2.73	1.99	1.69	.920	.990	.934	.1071	.1147	579.	619.
24.00	2.98	2.18	1.45	.920	.980	.931	.1138	.1222	670.	720.
26.00	3.22	2.36	1.25	.920	.973	.928	.1202	.1296	767.	827.
28.00	3.47	2.54	1.09	.920	.970	.924	.1260	.1363	866.	937.
30.00	3.72	2.72	.95	.920	.971	.920	.1299	.1412	956.	1040.
32.00	3.97	2.90	.83	.920	.973	.916	.1316	.1437	1034.	1129.

SAMPLE OUTPUT PAGE 3

PROPELLER CHARACTERISTICS IPROP = 1

D-IN	D-FT	P/D	EAR	BAR	BLADES	DEPTH-FT	SIGMA/VSQ	AP-SQ.FT
0.00	0.00	1.000	.700	.700	3.0	0.00	2368.4	0.00

OPEN-WATER

J	KT	KQ	EP	KT/J2	KQ/J2	KQ/J3	TC	QC	S.7/S
0.000	.453	.0693	0.000						
.005	.451	.0691	.005	18044.552	2764.0843	552816.8532	.4049	.06203	.0000
.010	.450	.0689	.010	4495.186	688.9063	68890.6270	.4035	.06184	.0000
.015	.448	.0687	.016	1990.727	305.2334	20348.8933	.4020	.06164	.0000
.020	.446	.0685	.021	1115.747	171.1570	8557.8476	.4006	.06145	.0001
.025	.445	.0682	.026	711.478	109.1943	4367.7718	.3991	.06125	.0001
.035	.441	.0678	.036	360.323	55.3542	1581.5498	.3961	.06085	.0003
.050	.436	.0671	.052	174.563	26.8564	537.1272	.3915	.06024	.0005
.075	.428	.0660	.077	76.072	11.7327	156.4364	.3837	.05917	.0012
.100	.419	.0648	.103	41.918	6.4815	64.8149	.3755	.05806	.0021
.125	.410	.0635	.128	26.255	4.0702	32.5617	.3671	.05690	.0032
.150	.401	.0623	.154	17.825	2.7709	18.4724	.3583	.05570	.0046
.175	.392	.0611	.179	12.790	1.9937	11.3928	.3494	.05446	.0063
.200	.382	.0597	.204	9.554	1.4935	7.4675	.3402	.05319	.0082
.225	.372	.0584	.228	7.356	1.1534	5.1262	.3308	.05187	.0104
.250	.362	.0570	.253	5.800	.9122	3.6488	.3212	.05052	.0128
.275	.352	.0556	.277	4.660	.7353	2.6737	.3115	.04914	.0154
.300	.342	.0542	.302	3.802	.6019	2.0063	.3015	.04774	.0183
.325	.332	.0527	.326	3.141	.4990	1.5355	.2914	.04630	.0214
.350	.321	.0512	.349	2.622	.4182	1.1948	.2812	.04485	.0247
.375	.310	.0497	.373	2.208	.3536	.9428	.2708	.04337	.0283
.400	.300	.0482	.396	1.673	.3012	.7530	.2604	.04187	.0320
.425	.289	.0466	.419	1.598	.2582	.6076	.2498	.04036	.0360
.450	.278	.0451	.441	1.371	.2226	.4946	.2392	.03883	.0402
.475	.266	.0435	.463	1.181	.1927	.4057	.2286	.03729	.0446
.500	.255	.0419	.485	1.021	.1675	.3350	.2178	.03575	.0492
.525	.244	.0403	.506	.885	.1461	.2782	.2071	.03419	.0539
.550	.232	.0386	.527	.768	.1277	.2322	.1964	.03263	.0589
.575	.221	.0370	.547	.668	.1119	.1945	.1856	.03107	.0640
.600	.209	.0353	.566	.582	.0981	.1636	.1749	.02951	.0693
.625	.198	.0337	.584	.506	.0862	.1379	.1642	.02796	.0747
.650	.186	.0320	.602	.440	.0757	.1165	.1536	.02640	.0803
.675	.174	.0303	.618	.383	.0665	.0985	.1430	.02486	.0861
.700	.163	.0286	.633	.332	.0584	.0834	.1325	.02332	.0920
.725	.151	.0269	.646	.287	.0512	.0706	.1220	.02179	.0980
.750	.139	.0252	.658	.247	.0448	.0598	.1117	.02028	.1042
.775	.127	.0235	.667	.212	.0392	.0505	.1015	.01878	.1105
.800	.115	.0218	.673	.180	.0341	.0426	.0914	.01730	.1169
.825	.103	.0201	.675	.152	.0296	.0358	.0814	.01583	.1234
.850	.092	.0184	.673	.127	.0255	.0300	.0716	.01439	.1300
.875	.080	.0167	.665	.104	.0218	.0250	.0619	.01296	.1367
.900	.068	.0150	.649				.0524	.01156	.1435

EPMAX = .675

SAMPLE OUTPUT PAGE 4

PROPELLER CHARACTERISTICS   IPROP = 1

D-IN	D-FT	P/D	EAR	BAR	BLADES	DEPTH-FT	SIGMA/VSQ	AP-SQ.FT
0.00	0.00	1.000	.700	.700	3.0	0.00	2296.5	0.00

T1	T2	Q1	Q2	TCX	QCX	RMAX	APD2
1.2000	1.0000	.2000	.9249	.0487	.0088	.8000	.2304

	OPEN WATER		SIGMA=25.00		SIGMA= 6.30		SIGMA= 3.50		SIGMA= 2.00		SIGMA= 1.50		SIGMA= 1.00		SIGMA= .75	
J	KT	KQ	KT	KQ	KT	KQ	KT	KQ	KT	KQ	KT	KQ	KT	KQ	KT	KQ
0.000	.453	.0693	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.005	.451	.0691	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.010	.450	.0689	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.015	.448	.0687	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.020	.446	.0685	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.025	.445	.0682	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.035	.441	.0678	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.050	.436	.0671	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.075	.428	.0660	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098	.054*	.0098
.100	.419	.0648	.055*	.0115	.054*	.0099	.054*	.0099	.054*	.0099	.054*	.0099	.054*	.0099	.054*	.0099
.125	.410	.0636	.086*	.0174	.054*	.0099	.054*	.0099	.054*	.0099	.054*	.0099	.054*	.0099	.054*	.0099
.150	.401	.0623	.124*	.0244	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099
.175	.392	.0611	.169*	.0324	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099
.200	.382	.0597	.221*	.0415	.056*	.0116	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099
.225	.372	.0584	.280*	.0516	.071*	.0144	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099	.055*	.0099
.250	.362	.0570	.346*	.0570	.087*	.0175	.055*	.0102	.055*	.0100	.055*	.0100	.055*	.0100	.055*	.0100
.275	.352	.0556	.352C	.0556	.105*	.0209	.059*	.0121	.055*	.0100	.055*	.0100	.055*	.0100	.055*	.0100
.300	.342	.0542	.342C	.0542	.125*	.0246	.070*	.0143	.055*	.0100	.055*	.0100	.055*	.0100	.055*	.0100
.325	.332	.0527	.332C	.0527	.147*	.0285	.082*	.0166	.055*	.0101	.055*	.0101	.055*	.0101	.055*	.0101
.350	.321	.0512	.321	.0512	.171*	.0327	.095*	.0190	.056*	.0113	.056*	.0101	.056*	.0101	.056*	.0101
.375	.310	.0497	.310	.0497	.196*	.0372	.109*	.0216	.062*	.0129	.056*	.0101	.056*	.0101	.056*	.0101
.400	.300	.0482	.300	.0482	.223*	.0419	.124*	.0243	.071*	.0145	.056*	.0111	.056*	.0102	.056*	.0102
.425	.289	.0466	.289	.0466	.252*	.0466	.140*	.0272	.080*	.0162	.060*	.0124	.056*	.0102	.056*	.0102
.450	.278	.0451	.278	.0451	.278C	.0451	.157*	.0303	.090*	.0180	.067*	.0138	.057*	.0102	.057*	.0102
.475	.266	.0435	.266	.0435	.266C	.0435	.175*	.0335	.100*	.0199	.075*	.0153	.057*	.0105	.057*	.0103
.500	.255	.0419	.255	.0419	.255C	.0419	.194*	.0368	.111*	.0219	.083*	.0168	.057*	.0116	.057*	.0103
.525	.244	.0403	.244	.0403	.244C	.0403	.213*	.0403	.122*	.0240	.091*	.0184	.061*	.0127	.057*	.0104
.550	.232	.0386	.232	.0386	.232	.0386	.232C	.0386	.134*	.0262	.100*	.0201	.067*	.0138	.058*	.0106
.575	.221	.0370	.221	.0370	.221	.0370	.221C	.0370	.146*	.0284	.110*	.0218	.073*	.0150	.058*	.0115
.600	.209	.0353	.209	.0353	.209	.0353	.209C	.0353	.159*	.0308	.119*	.0236	.080*	.0162	.060*	.0124
.625	.198	.0337	.198	.0337	.198	.0337	.198C	.0337	.173*	.0332	.130*	.0255	.086*	.0175	.065*	.0134
.650	.186	.0320	.186	.0320	.186	.0320	.186	.0320	.186C	.0320	.140*	.0274	.093*	.0188	.070*	.0144
.675	.174	.0303	.174	.0303	.174	.0303	.174	.0303	.174C	.0303	.151*	.0294	.101*	.0202	.076*	.0155
.700	.163	.0286	.163	.0286	.163	.0286	.163	.0286	.163C	.0286	.163C	.0286	.108*	.0216	.081*	.0166
.725	.151	.0269	.151	.0269	.151	.0269	.151	.0269	.151C	.0269	.151C	.0269	.116*	.0231	.087*	.0177
.750	.139	.0252	.139	.0252	.139	.0252	.139	.0252	.139	.0252	.139C	.0252	.124*	.0246	.093*	.0188
.775	.127	.0235	.127	.0235	.127	.0235	.127	.0235	.127	.0235	.127	.0235	.127C	.0235	.100*	.0200
.800	.115	.0218	.115	.0218	.115	.0218	.115	.0218	.115	.0218	.115	.0218	.115C	.0218	.106*	.0212
.825	.103	.0201	.103	.0201	.103	.0201	.103	.0201	.103	.0201	.103	.0201	.103C	.0201	.103C	.0201
.850	.092	.0184	.092	.0184	.092	.0184	.092	.0184	.092	.0184	.092	.0184	.092	.0184	.092C	.0184
.875	.080	.0167	.080	.0167	.080	.0167	.080	.0167	.080	.0167	.080	.0167	.080	.0167	.080	.0167
.900	.068	.0150	.068	.0150	.068	.0150					.068	.0150	.068	.0150	.068	.0150

SAMPLE OUTPUT PAGE 5

PLANING HULL WITH PROPELLERS NO. 5 PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

PROPELLER SIZING VA(FPS) = 36.8 P/D = 1.00 EAR = .700 3.BLADES NPR = 2.

	DIN	D-FT	SIGMA	KT/JSQ	JT	KT	KQ	EP	PC	T-LB	Q-FT.LB	RPM	DHP
MIN. DIAM.	35.76	2.98	1.75	.246	.751	.139	.0252	.658	.611	11749.C	6359.	986.	1194.
MAX. DIAM.	45.46	3.79	1.78	.152	.825	.103	.0201	.675*	.627	11749.	8654.	706.	1163.
	55.00	4.58	1.80	.104	.876	.080	.0167	.665*	.618	11749.	11284.	550.	1181.
	50.00	4.17	1.79	.126	.951	.091	.0183	.673*	.625	11749.	9855.	622.	1167.
	45.00	3.75	1.77	.155	.822	.105	.0203	.675	.627	11749.	8537.	716.	1163.
	40.00	3.33	1.76	.196	.787	.122	.0227	.670	.622	11749.	7320.	841.	1173.
	35.00	2.92	1.74	.256	.744	.142	.0256	.655	.608	11749.C	6194.	1017.	1200.
	30.00	2.50	1.73	.349	.691	.167	.0292	.628	.583	11749.C	5147.	1277.	1252.
OPT. DIAM.	37.00	3.08	1.75	.229	.762	.133	.0244	.662	.615	11749.	6634.	939.	1186.
	51.41	4.28	1.79	.119	.859	.088	.0178	.671*	.624	11749.	10246.	600.	1170.
	45.75	3.81	1.78	.150	.827	.103	.0200	.675*	.627	11749.	8728.	700.	1163.
	41.47	3.46	1.76	.183	.798	.116	.0220	.672	.625	11749.	7668.	800.	1168.
	38.10	3.18	1.75	.216	.771	.129	.0238	.665	.618	11749.	6883.	901.	1181.
	35.39	2.95	1.75	.251	.747	.140	.0254	.656	.610	11749.C	6279.	1001.	1197.

SAMPLE OUTPUT PAGE 6

PLANING HULL WITH PROPELLERS NO. 5 PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

LOA-FT	LP-FT	BPX-FT	HT-FT	DISPL-LB	BETA-DEG	LCG-FT	VCG-FT	XACC-FT	C-LOAD	LP/V13	LP/BPX	D-IN	P/D	EAR	NPR
65.00	60.00	15.00	2.00	80000.	20.00	24.00	8.00	45.00	.370	5.57	4.00	37.0	1.00	.700	2

V-KT	H13-FT	RW/W	KT/JSQ	JT	KT	KQ	EP	PC	T-LB	Q-FT.LB	RPM	DHP	TRIM	CG ACC	X ACC	BOW ACC
6.00	0.00	.1813	0.000	.747	.140	.0254	.656	.608	0.	0.	0.	0.	2.50	0.00	0.00	0.00
6.00	1.00	.0025	.050	.949	.045	.0118	.583*	.510	217.	173.	219.	7.	2.50	.05	.16	.24
6.00	3.00	.0043	.087	.896	.070	.0153	.653*	.571	375.	253.	231.	11.	2.50	.16	.49	.71
6.00	5.00	.0056	.113	.865	.084	.0174	.669*	.585	485.	308.	240.	14.	2.50	.27	.82	1.18
6.00	8.00	.0071	.143	.834	.099	.0195	.675*	.590	613.	372.	249.	18.	2.50	.44	1.32	1.88
8.00	0.00	.0082	.092	.889	.073	.0157	.657*	.571	714.	474.	313.	28.	2.50	0.00	0.00	0.00
8.00	1.00	.0115	.130	.847	.093	.0186	.674*	.586	1003.	619.	328.	39.	2.50	.07	.21	.29
8.00	3.00	.0140	.157	.820	.106	.0204	.675	.587	12:5.	724.	339.	47.	2.50	.22	.62	.88
8.00	5.00	.0156	.176	.803	.114	.0216	.673	.585	1360.	797.	346.	52.	2.50	.37	1.03	1.46
8.00	8.00	.0176	.198	.785	.122	.0228	.670	.582	1532.	862.	354.	59.	2.50	.59	1.65	2.33
10.00	0.00	.0303	.217	.771	.129	.0238	.665	.577	2632.	1497.	452.	129.	2.50	0.00	0.00	0.00
10.00	1.00	.0344	.247	.750	.139	.0252	.658	.570	2993.	1676.	464.	148.	2.50	.09	.25	.34
10.00	3.00	.0375	.269	.736	.146	.0262	.651	.565	3258.	1806.	473.	163.	2.50	.27	.74	1.03
10.00	5.00	.0396	.284	.727	.150	.0268	.647	.561	3440.	1896.	479.	173.	2.50	.46	1.23	1.72
10.00	8.00	.0420	.301	.717	.155	.0275	.642	.557	3654.	2002.	486.	185.	2.50	.73	1.97	2.76
12.00	0.00	.0580	.290	.723	.152	.0270	.645	.561	5043.	2774.	577.	305.	2.50	0.00	0.00	0.00
12.00	1.00	.0630	.315	.709	.158	.0280	.638	.554	5476.	2987.	588.	335.	2.50	.11	.28	.40
12.00	3.00	.0566	.333	.699	.163	.0287	.632	.550	5794.	3144.	597.	357.	2.50	.33	.85	1.19
12.00	5.00	.0691	.346	.693	.166	.0291	.629	.546	6012.	3251.	602.	373.	2.50	.55	1.42	1.98
12.00	8.00	.0721	.360	.686	.169	.0296	.624	.543	6269.	3378.	609.	391.	2.50	.88	2.27	3.16
14.00	0.00	.0822	.305	.715	.156	.0276	.641	.560	7145.	3909.	678.	504.	2.50	0.00	0.00	0.00
14.00	1.00	.0880	.327	.703	.161	.0284	.634	.554	7650.	4159.	689.	546.	2.50	.13	.32	.44
14.00	3.00	.0922	.342	.695	.165	.0290	.630	.550	8021.	4341.	697.	576.	2.50	.38	.96	1.33
14.00	5.00	.0952	.353	.689	.168	.0294	.626	.547	8275.	4466.	703.	598.	2.50	.64	1.60	2.22
14.00	8.00	.0986	.366	.683	.171	.0298	.623	.544	8575.	4614.	709.	623.	2.50	1.03	2.56	3.55
16.00	0.00	.0918	.266	.738	.145	.0260	.652	.575	7986.	4433.	743.	627.	2.50	0.00	0.00	0.00
16.00	1.00	.0985	.285	.726	.150	.0268	.647	.570	8564.	4718.	755.	678.	2.50	.15	.36	.49
16.00	3.00	.1033	.299	.718	.154	.0274	.643	.567	8987.	4927.	764.	717.	2.50	.44	1.07	1.47
16.00	5.00	.1067	.309	.712	.157	.0278	.640	.564	9278.	5071.	770.	743.	2.50	.73	1.78	2.45
16.00	8.00	.1106	.320	.706	.160	.0282	.636	.561	9621.	5239.	776.	775.	2.50	1.17	2.85	3.93
18.00	0.00	.0989	.233	.759	.135	.0246	.661	.592	8598.	4846.	800.	738.	2.50	0.00	0.00	0.00
18.00	1.00	.1064	.251	.747	.140	.0254	.656	.588	9249.	5167.	813.	799.	2.50	.16	.39	.54
18.00	3.00	.1118	.264	.739	.144	.0260	.653	.585	9725.	5403.	822.	845.	2.50	.49	1.17	1.61
18.00	5.00	.1156	.273	.734	.147	.0263					828.	877.	2.50	.82	1.95	2.68
18.00	8.00	.1200	.283	.727	.150	.0268					835.	915.	2.50	1.32	3.13	4.29

SAMPLE OUTPUT PAGE 7

LOA-FT	LP-FT	BPX-FT	HT-FT	DISPL-LB	BETA-DEG	LCG-FT	VCG-FT	XACC-FT	C-LOAD	LP/V13	LP/BPX	D-IN	P/D	EAR	NPR
65.00	60.00	15.00	2.00	80000.	20.00	24.00	8.00	45.00	.370	5.57	4.00	37.0	1.00	.700	2

V-KT	H13-FT	RW/Δ	KT/JSQ	JT	KT	KQ	EP	PC	T-LB	Q-FT.LB	RPM	DHP	TRIM	CG ACC	X ACC	BOW ACC
20.00	0.00	.1064	.211	.776	.127	.0235	.667	.608	9250.	5280.	854.	859.	2.50	0.00	0.00	0.00
20.00	1.00	.1147	.227	.763	.133	.0243	.663	.605	9972.	5638.	868.	931.	2.50	.18	.42	.58
20.00	3.00	.1208	.239	.755	.137	.0249	.660	.602	10501.	5899.	877.	985.	2.50	.55	1.27	1.74
20.00	5.00	.1250	.248	.749	.139	.0253	.657	.600	10865.	6079.	884.	1023.	2.50	.92	2.12	2.90
20.00	8.00	.1299	.258	.743	.142	.0257	.655	.597	11293.	6291.	891.	1058.	2.50	1.47	3.40	4.64
22.00	0.00	.1147	.195	.788	.121	.0226	.670	.623	9972.	5754.	908.	995.	2.50	0.00	0.00	0.00
22.00	1.00	.1238	.210	.776	.127	.0235	.667	.619	10766.	6148.	922.	1080.	2.50	.20	.46	.62
22.00	3.00	.1305	.222	.768	.131	.0240	.654	.617	11348.	6436.	932.	1143.	2.50	.60	1.37	1.87
22.00	5.00	.1351	.229	.762	.133	.0244	.662	.615	11749.	6634.	939.	1186.	2.50	1.01	2.29	3.12
22.00	8.00	.1405	.239	.756	.136	.0248	.660	.613	12219.	6867.	947.	1238.	2.50	1.61	3.67	4.98
24.00	0.00	.1222	.178	.802	.115	.0217	.673	.632	10624.	6210.	963.	1139.	2.50	0.00	0.00	0.00
24.00	1.00	.1321	.193	.790	.120	.0225	.671	.630	11491.	6640.	978.	1237.	2.50	.22	.49	.67
24.00	3.00	.1394	.203	.781	.124	.0231	.668	.528	12126.	6955.	989.	1309.	2.50	.66	1.47	2.00
24.00	5.00	.1445	.211	.776	.127	.0235	.667	.626	12563.	7171.	996.	1360.	2.50	1.10	2.45	3.33
24.00	8.00	.1504	.219	.769	.130	.0239	.665	.624	13076.C	7426.	1004.	1419.	2.50	1.76	3.93	5.32
26.00	0.00	.1296	.163	.815	.108	.0209	.675	.638	11267.	6675.	1020.	1296.	2.50	0.00	0.00	0.00
26.00	1.00	.1404	.177	.803	.114	.0216	.673	.637	12206.	7142.	1035.	1408.	2.50	.24	.52	.71
26.00	3.00	.1483	.187	.794	.118	.0222	.672	.635	12894.C	7484.	1046.	1490.	2.50	.71	1.57	2.12
26.00	5.00	.1537	.194	.789	.121	.0226	.670	.634	13367.C	7719.	1053.	1548.	2.50	1.19	2.62	3.53
26.00	8.00	.1601	.202	.782	.124	.0230	.669	.632	13924.C	7995.	1062.	1616.	2.50	1.91	4.18	5.65
28.00	0.00	.1363	.149	.828	.102	.0199	.675•	.641	11852.	7129.	1077.	1462.	2.50	0.00	0.00	0.00
28.00	1.00	.1479	.162	.816	.108	.0207	.675	.640	12863.	7632.	1093.	1598.	2.50	.26	.55	.75
28.00	3.00	.1564	.171	.808	.112	.0213	.674	.639	13604.C	8001.	1104.	1682.	2.50	.77	1.66	2.24
28.00	5.00	.1623	.178	.802	.114	.0217	.673	.639	14114.C	8254.	1112.	1747.	2.50	1.28	2.77	3.73
28.00	8.00	.1692	.185	.796	.117	.0221	.672	.637	14713.C	8552.	1121.	1825.	2.50	2.05	4.44	5.97
30.00	0.00	.1412	.134	.842	.095	.0189	.674•	.639	12276.	7524.	1135.	1626.	2.50	0.00	0.00	0.00
30.00	1.00	.1536	.146	.831	.101	.0197	.675•	.640	13359.C	8064.	1151.	1758.	2.50	.27	.59	.79
30.00	3.00	.1628	.155	.822	.105	.0203	.675	.640	14153.C	8459.	1163.	1873.	2.50	.82	1.76	2.36
30.00	5.00	.1690	.161	.817	.107	.0207	.675	.640	14699.C	8730.	1171.	1946.	2.50	1.37	2.93	3.93
30.00	8.00	.1764	.168	.811	.110	.0211	.674	.639	15341.C	9050.	1180.	2033.	2.50	2.20	4.69	6.29
32.00	0.00	.1437	.120	.858	.088	.0179	.671•	.635	12498.	7836.	1192.	1779.	2.50	0.00	0.00	0.00
32.00	1.00	.1570	.131	.846	.093	.0187	.674•	.637	13654.C	8413.	1209.	1936.	2.50	.29	.62	.83
32.00	3.00	.1668	.139	.838	.097	.0192	.675•	.638	14500.C	8835.	1221.	2053.	2.50	.88	1.85	2.48
32.00	5.00	.1735	.144	.832	.100	.0196					1229.	2135.	2.50	1.47	3.09	4.13
32.00	8.00	.1813	.151	.826	.103	.0200					1238.	2231.	2.50	2.35	4.94	6.60

SAMPLE OUTPUT PAGE 7

PLANING HULL WITH PROPELLERS NO. 5 PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

LOA-FT	LP-FT	BPX-FT	HT-FT	DISPL-LB	BETA-DEG	LCG-FT	VCG-FT	XACC-FT	C-LOAD	LP/V13	LP/BPX	D-IN	P/D	EAR
65.00	60.00	15.00	2.00	80000.	20.00	24.00	8.00	45.00	.370	5.57	4.00	37.0	1.00	.700

NPR
2

10 PERCENT BACK CAVITATION

V-KT	SIGMA	T-LB	Q-FT.LB	RPM	DHP	J	KT	KQ	EP
6.00	20.86	11018.	5421.	587.	606.	.353	.320	.0510	.352
8.00	11.60	11230.	5610.	631.	674.	.440	.282	.0457	.433
10.00	7.39	11443.	5808.	678.	750.	.514	.249	.0410	.497
12.00	5.15	11651.	6013.	726.	831.	.575	.221	.0370	.546
14.00	3.82	11849.	6220.	774.	917.	.625	.198	.0337	.584
16.00	2.98	12035.	6427.	822.	1006.	.657	.178	.0309	.613
18.00	2.43	12203.	6625.	867.	1094.	.700	.162	.0286	.633
20.00	2.04	12355.	6815.	910.	1181.	.728	.149	.0267	.648
22.00	1.75	12499.	7006.	952.	1270.	.752	.138	.0251	.658
24.00	1.50	12649.	7214.	997.	1370.	.775	.127	.0235	.666
26.00	1.30	12800.	7437.	1044.	1479.	.796	.117	.0221	.672
28.00	1.13	12953.	7677.	1094.	1600.	.815	.108	.0208	.675
30.00	.98	13111.	7940.	1148.	1735.	.833	.100	.0196	.675
32.00	.86	13269.	3220.	1203.	1883.	.850	.092	.0184	.673

MAXIMUM SPEED WITH OPTIMUM GEAR RATIO

V-KT = 2:.88 H13-FT = 5.00 DHP = 1176. RPM-P = 936. OPT. GEAR RATIO = 2.46

SAMPLE OUTPUT PAGE 8

PLANING HULL WITH PROPELLERS   NO. 5   PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

LOA-FT	LP-FT	BPX-FT	HT-FT	DISPL-LB	BETA-DEG	LCG-FT	VCG-FT	XACC-FT	C-LOAD	LP/V13	LP/BPX	D-IN	P/D	EAR
65.00	60.00	15.00	2.00	80000.	20.00	24.00	8.00	45.00	.370	5.57	4.00	37.0	1.00	.700

THRUST AT MAXIMUM RPM OF PRIME MOVERS WITH GEAR RATIO OF 2.46

V-KT	SIGMA	T-LB	Q-FT.LB	RPM	DHP	J	KT	KQ	EP
6.00	20.86	19814. *	11451. *	936.	2041.	.222	.226	.0424	.188
8.00	11.60	19814. *	11458. *	936.	2042.	.297	.226	.0424	.252
10.00	7.39	19814. *	11467. *	936.	2043.	.372	.226	.0425	.316
12.00	5.15	19814. *	11477. *	936.	2045.	.446	.226	.0425	.378
14.00	3.82	19814. *	11005. *	936.	1961.	.517	.226	.0409	.457
16.00	2.98	18908. C	9792. *	936.	1745.	.580	.216	.0363	.555
18.00	2.43	16335. C	8656. *	936.	1543.	.649	.187	.0321	.601
20.00	2.04	13914. C	7584. *	936.	1352.	.708	.159	.0281	.637
22.00	1.75	11559.	6540.	936.	1165.	.765	.132	.0242	.663
24.00	1.50	9054.	5429.	936.	967.	.825	.103	.0201	.675
26.00	1.30	6474.	4284.	936.	763.	.883	.074	.0159	.658
28.00	1.13	3802.	3098.	936.	552.	.953	.043	.0115	.574
30.00	.98	1016.	1862.	936.	332.	1.022	.012	.0069	.274
32.00	.86	-1805.	613.	936.	109.	1.093	-.021	.0023	-1.579

THRUST AT TORQUE LIMITS OF PRIME MOVERS WITH GEAR RATIO OF 2.46

V-KT	SIGMA	T-LB	Q-FT.LB	RPM	DHP	J	KT	KQ	EP
0.00	0.00	0.	6327.	0.	0.	0.000	0.000	0.0000	0.000
0.00	0.00	0.	6529.	0.	0.	0.000	0.000	0.0000	0.000
6.58	17.24	13606. C	6691.	651.	829.	.350	.321	.0512	.349
8.68	9.83	13569. C	6773.	692.	892.	.436	.284	.0459	.429
10.73	6.42	13445. C	6819.	732.	951.	.510	.251	.0412	.493
12.72	4.60	13304. C	6859.	773.	1010.	.571	.223	.0372	.544
14.77	3.45	13061. C	6858.	814.	1063.	.626	.197	.0336	.585
16.97	2.69	12697. C	6808.	855.	1108.	.676	.174	.0303	.618
19.35	2.16	12256.	6729.	895.	1147.	.720	.153	.0272	.644
21.88	1.77	11698.	6602.	936.	1176.	.761	.134	.0245	.662

SPEED-POWER LIMITS WITH GEAR RATIO OF 2.46

V-KT	H13-FT	T-LB	Q-FT.LB	RPM	DHP
23.01	0.00	10306.	5985.	936.*	1067.
22.49	1.00	10950.	6270.	936.*	1117.
22.13	3.00	11400.	6470.	936.*	1153.
21.68	5.00	11698.	6602.	936.*	1176.
21.25	8.00	11874.	6651.*	926.	1173.

SAMPLE OUTPUT PAGE 9

PLANING HULL WITH PROPELLERS NO. 5 PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

LOA-FT	LP-FT	BPX-FT	HT-FT	DISPL-LB	BETA-DEG	LCG-FT	VCG-FT	XACC-FT	C-LOAD	LP/V13	LP/BPX	D-IN	P/D	EAR
65.00	60.00	15.00	2.00	80000.	20.00	24.00	8.00	45.00	.370	5.57	4.00	37.0	1.00	.700

THRUST AT MAXIMUM RPM OF PRIME MOVERS WITH GEAR RATIO OF 2.00

V-KT	SIGMA	T-LB	Q-FT.LB	RPM	DHP	J	KT	KQ	EP
6.00	20.86	19814. *	11808. *	1150.	2585.	.180	.150	.0290	.148
8.00	11.60	19814. *	11813. *	1150.	2587.	.242	.150	.0290	.199
10.00	7.39	19814. *	11819. *	1150.	2588.	.303	.150	.0290	.249
12.00	5.15	19814. *	11826. *	1150.	2589.	.363	.150	.0290	.298
14.00	3.82	19814. *	11834. *	1150.	2591.	.421	.150	.0290	.346
16.00	2.98	19814. *	11843. *	1150.	2593.	.477	.150	.0291	.391
18.00	2.43	19814. *	11852. *	1150.	2595.	.528	.150	.0291	.433
20.00	2.04	19814. *	11861. *	1150.	2597.	.576	.150	.0291	.472
22.00	1.75	19814. *	11871. *	1150.	2599.	.622	.150	.0291	.510
24.00	1.50	19814. *	11881. *	1150.	2602.	.672	.150	.0292	.550
26.00	1.30	19814. *	11041. *	1150.	2418.	.722	.150	.0271	.636
28.00	1.13	16769. C	9571. *	1150.	2096.	.776	.127	.0235	.667
30.00	.98	13266. C	8017. *	1150.	1755.	.832	.100	.0197	.675
32.00	.86	9663.	6418. *	1150.	1405.	.889	.073	.0157	.657

THRUST AT TORQUE LIMITS OF PRIME MOVERS WITH GEAR RATIO OF 2.00

V-KT	SIGMA	T-LB	Q-FT.LB	RPM	DHP	J	KT	KQ	EP
12.46	4.78	9833.	5149.	700.	686.	.618	.201	.0341	.580
14.55	3.55	9938.	5314.	750.	759.	.670	.177	.0307	.615
16.78	2.74	9949.	5445.	800.	829.	.715	.156	.0276	.641
19.30	2.17	9800.	5512.	850.	892.	.757	.136	.0248	.660
21.96	1.76	9566.	5550.	900.	951.	.794	.118	.0222	.672
24.42	1.46	9305.	5583.	950.	1010.	.826	.103	.0201	.675
26.79	1.23	8949.	5582.	1000.	1063.	.855	.090	.0181	.672
29.04	1.05	8485.	5541.	1050.	1108.	.881	.077	.0163	.662
31.19	.90	7953.	5478.	1100.	1147.	.905	.066	.0147	.645
33.31	.79	7291.	5365.	1150.	1175.	.928	.055	.0132	.619

SPEED-POWER LIMITS WITH GEAR RATIO OF 2.00

V-KT	H13-FT	T-LB	Q-FT.LB	RPM	DHP
21.10	0.00	9647.	5539.*	864.	932.
19.49	1.00	9783.	5515.*	854.	896.
18.35	3.00	9855.	5486.*	831.	869.
17.60	5.00	9902.	5468.*	817.	850.
16.77	8.00	9949.	5445.*	800.	829.

SAMPLE OUTPUT PAGE 9

PLANING HULL WITH PROPELLERS — PLANING CRAFT WITH 2 PROPELLERS AND DIESEL ENGINES

LOA-FT	LP-FT	BPX-FT	HT-FT	DISPL-LB	BETA-DEG	LCG-FT	VCG-FT	XACC-FT	C-LOAD	LP/V13	LP/BPX
65.00	60.00	15.00	2.00	80000.	20.00	24.00	8.00	45.00	.370	5.57	4.00

HABITABILITY LIMITS OF 1.0 G AND 1.5 G AVERAGE 1/10 HIGHEST ACCELERATIONS -- 45.00 FT FWD OF TRANSOM

	(1.0 G)	(1.5 G)
V-KT	H13-FT	H13-FT
6.00	6.07	9.11
8.00	4.85	7.27
10.00	4.07	6.10
12.00	3.52	5.29
14.00	3.12	4.68
16.00	2.81	4.21
18.00	2.56	3.84
20.00	2.35	3.53
22.00	2.18	3.27
24.00	2.04	3.06
26.00	1.91	2.87
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